REPORT RESUMES

ED 015 492 24 CG 000 974

LEARNING ABOUT LEARNING. A CONFERENCE REPORT.
BY- BRUNER, JEROME
OFFICE OF EDUCATION (DHEW), WASHINGTON, D.C.
REPORT NUMBER COOP-RES-MONOGR-15 PUB DATE 66
REPORT NUMBER CRP-F-016
REPORT NUMBER BR-5-0615
EDRS PRICE MF-$1.25 HC NOT AVAILABLE FROM EDRS. 280P.

DESCRIPTORS- SCIENCE EDUCATION, ATTITUDES, SKILLS, *SELF CONCEPT, COGNITIVE ABILITY, *CURRICULUM RESEARCH, *CURRICULUM DEVELOPMENT, STIMULUS BEHAVIOR, ATTENTION CONTROL, READING PROCESSES, *LEARNING MOTIVATION, ATTENTION, CONFERENCES,

TO EXPLORE THE NATURE OF THE LEARNING PROCESS, THREE IMPORTANT PROBLEM AREAS WERE STUDIED. STUDIES IN THE FIRST AREA, ATTITUDINAL AND AFFECTIVE SKILLS, ARE CONCERNED WITH INDUCING A CHILD TO LEARN AND SUSTAINING HIS ATTENTION. STUDIES IN THE SECOND AREA, COGNITIVE SKILLS, SOUGHT TO DISCOVER WHETHER GENERAL IDEAS AND SKILLS CAN BE LEARNED IN SUCH A WAY IN ONE SUBJECT THAT THEY WILL MATERIALLY AFFECT PROGRESS IN ANOTHER. STUDIES IN THE THIRD AREA, STIMULUS CONTROL, ARE CONCERNED WITH PRESENTING LEARNING MATERIALS IN AN OPTIONAL SEQUENCE. WORKING PAPERS AND NOTES ON THE PLENARY SESSIONS ARE APPENDED. THIS MONOGRAPH PRESENTS THE RESULTS OF THE WORKING CONFERENCE ON RESEARCH ON CHILDREN'S LEARNING (CAMBRIDGE, MASS., JUNE 14-28, 1963). IT IS AVAILABLE AS CATALOG NO-FS-5.212--12019 FROM THE SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402, FOR $1.00. (JB)

ED015492

CRP-F-011
BR 5-0615
PA24

LEARNING
ABOUT
LEARNING

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY.

OE-12019
Cooperative Research
Monograph No. 15

LEARNING ABOUT LEARNING:
a conference report

Edited by
JEROME BRUNER, ***Director***
Center for Cognitive Studies
Harvard University

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Office of Education

CG 000 974

The research reported herein was performed pursuant to a contract with the Office of Education, U.S. Department of Health, Education, and Welfare under the provisions of Public Law 83-531, the Cooperative Research Program.

Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

A publication of the
BUREAU OF RESEARCH
(R. Louis Bright, Associate Commissioner)
Francis A. J. Ianni, Deputy Associate Commissioner

Superintendent of Documents Catalog No. FS 5.212:12019

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1966

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 Price $1.00

FOREWORD

This monograph presents the results of the Working Conference on Research on Children's Learning, supported by the U.S. Office of Education through the Cooperative Research Program. The conference represents a major attempt to answer a number of important questions about the nature of the learning process. Some of the Nation's most distinguished specialists in learning, child development, and "cognition" participated in this conference held at Cambridge, Mass., June 14–28, 1963.

Discovering more about how children learn, or "learning about learning," had been established as a major goal for educational research by a Panel on Educational Research and Development of the President's Science Advisory Committee. As a result of the recommendations of this Panel, the Working Conference was set up to study the nature of the learning process. Three important problems were studied, each of which forms a chapter in this monograph. The first chapter is concerned with inducing a child to learn and sustaining his attention. The second asks whether general ideas and skills can be learned in such a way in one subject that they will materially affect progress in another. The third chapter is concerned with presenting learning materials in an optional sequence.

It is difficult to conceive of any problems that are more crucial to students' learning. The Office of Education presents this conference report in the hope of stimulating thought and research on the problems of learning, and thus shortening the path toward their solution.

Francis A. J. Ianni
Deputy Associate
Commissioner
Bureau of Research

PREFACE

In 1961, President Kennedy established a White House Panel on Educational Research and Development, which was to advise the U.S. Office of Education, the National Science Foundation, and his science adviser on improving American education. The Panel was chaired by the dynamic and difficult-to-satisfy physicist Professor Jerrold Zacharias, of the Massachusetts Institute of Technology, and the "hosts" at our meetings in Washington were Jerome Weisner, Alan Waterman, and Sterling McMurrin. Later, Francis Keppel, who had been a member of the Panel from the start, succeeded Dr. McMurrin as Commissioner of Education.

The Panel settled upon three high-priority goals—one immediate, one middling, and one long-range. The immediate goal was to help unravel the pressing problem of the great urban school systems with their Negro in-migrants, so ill-prepared for school and so alienated from the society that they dropped out of school at a rate alarming not only in itself but for what it presaged as a later problem in unemployability. Here was a major waste of human resources. The problems were critical and immediate; the crisis was in full being.

The middling goal—to improve instruction through new, more daring curriculums—was to be paralleled by better recruitment and training of teachers. The astonishing progress in the five years preceding was reason to believe that wise planning could accelerate the already promising rate of improvement. We had begun to learn, as a Nation, how to construct curriculums for schools—indeed, the progress stemmed from a revolutionary conception (quite ordinary common sense in retrospect): that the preparation of materials for the classroom was the responsibility, not only of teachers and schoolmen, but also of outstanding scholars and scientists. Nobel laureates in physics and biology, distinguished historians and literary men could be found summers in Boulder, Colo., or Palo Alto, Calif., or even in such less climatically blessed locales as Cambridge, Mass., working beside specially gifted schoolteachers on a new curriculum in mathematics or American history or geology—or indeed, in subjects that were nameless in their generality and had as their sole aim to teach how to learn better, to learn anything better.

The third goal was virtually forced on the Panel by the nature of its task. Whether one asked how an underprivileged child can be induced to treat school learning as worth a try or how much a kindergarten child can learn about mathematical operations, the issue always arose: What is the nature of learning? How does it proceed. How can children be helped to grasp physics or mathematics or poetry?

Accordingly, in November 1962, a preliminary meeting was called in Chicago, a meeting of some of the Nation's most distinguished specialists in learning, child development, and that related series of disciplines that psychologists call "cognition"—thought, memory, perception, problem-solving. The meeting struggled to convert the question into more manageable form, to translate it into a set of questions that were sufficiently modest and specific as to be promising of an answer. Three component groups of questions emerged. The first was:

How can children be predisposed to engage in learning? What are the inducements necessary. How can attention be recruited and sustained. How can children be led to some intrinsic satisfaction in their own progress? How is all this affected by home, by background, by social conditions? The questions are familiar to psychologists—although many issues still remain obscure.

The second group had to do with skills and their generality. Here is the heart of intellectual power. A child can learn a specific intellectual skill—let us say that it is mastery of the multiplication table. But if that is all that he learns, the result is somehow a waste of good effort. For there is a step beyond that renders specific bits of knowledgeable competence into a more powerful form. That 6 × 3 and 3 × 6 equal the same thing is not just a given of multiplication tables, but rather, a powerful rule of mathematical operations that goes by the forbidding name of commutativity. The rule is not obvious and there are occasions when we would correct a child who said that three cars with six people in each was the same thing as six cars with three occupants each. And the absence of 19 in the multiplication table is not by chance but relates to a wide range of operations called factoring and non-factorability or prime numbers.

In a still more general sense, these and other operations are part of an even more general competence by which one tests mathematics as a set of rules for reasoning about order, magnitude, and relation. Can general ideas and skills of this order be learned in one subject in such a way that they will affect progress in another? Does the child who learns early what mathematics is—and there is enough work now in existence to indicate that it is no more difficult to teach young children this truth than it is to teach them an unrelated set of computational skills—does this child develop a more searching attitude toward other subjects? What is it to instill in a child the conviction that it is not worth going on unless what he is doing makes sense to him? Viewed in this light, the question of what skills one is teaching soon fuses with a related one about the kind of intellectual attitudes one seeks to create.

The third component group of questions that grew out of the Chicago discussion dealt with the arrangement of learning situations themselves. How does one present materials in order to lead the child to discover for himself? Or how does one set up a series of encounters with a subject so that a child is able to discern what is simply vivid in contrast to what is relevant? The problem of sequence arises from an odd circumstance. A body of knowledge and skills for manipulating that knowledge "exists" in a simultaneous sense. It is a part of the culture. But one cannot encounter or present it all at once in its connected fullness. What should be given first, what next, and how shall a next step be influenced by how the child has proceeded up to here? The questions, interestingly enough, remain recognizably the same, whether one is asking how to arrange exercises for a kindergartner or freshman, how to program a teaching machine, how to organize the chapters and sections of a book, how to present a lecture. They are universal problems of arranging the order of an informational environment.

The group disbanded with the intention of coming together for a fortnight of work in Cambridge the following June. Working papers were prepared in the meantime on various of the topics discussed and new members chosen to cover topics in which the original group felt no particular competence. Cambridge was chosen as a meeting place because there were also congregated there at the same time several other working parties attacking problems of curriculum—a new, daring, and highly gifted group of mathematicians working on school mathematics under the direction of Professor Andrew Gleason of Harvard, an elementary science group directed by Professor David Hawkins of

Colorado trying out materials in a specially arranged summer school for young children, and a social studies group under the wing of Professor Elting Morison of M.I.T.

This monograph contains the tangible results of the Working Conference on Research on Children's Learning, held at Harvard University June 14-28, 1964. The 26 professional participants were the following:

Alfred Baldwin, Cornell University
Daniel Berlyne, University of Toronto
Roger W. Brown, Harvard University
Jerome S. Bruner, Harvard University
Richard Crutchfield, University of California (Berkeley)
Robert Davis, Madison Project, Webster College
Margaret Donaldson, University of Rhode Island
Richard L. Garwin, Columbia University
Eleanor J. Gibson, Cornell University
Jacqueline Goodnow, George Washington University
David Hawkins, Educational Services, Inc.
Mary Henle, New School for Social Research
Jerome Kagan, Fels Research Institute
William Kessen, Yale University
Clementina Kuhlman, Harvard University
Harry Levin, Cornell University
Lloyd N. Morrisett, Carnegie Corporation
Philip Morrison, Cornell University
Paul H. Mussen, University of California (Berkeley)
Rose Olver, Amherst College
Frank Restle, Indiana University
Pauline S. Sears, Stanford University
Robert R. Sears, Stanford University
Harold W. Stevenson, University of Minnesota
Patrick Suppes, Stanford University
John W. M. Whiting, Harvard University

During the first several days of the conference the participants met as a whole to discuss the preliminary working papers (selections included in Appendix A) that had been mailed to them earlier. Throughout the two weeks, members occasionally met again in plenary session with representatives of curriculum development projects in mathematics, elementary science, and social studies. Summaries of all the plenary sessions appear in Appendix B. While these notes were intended to serve as a record for the participants themselves and so may not be comprehensible to those not attending the conference, they do convey something of the flavor of the discussions.

Three working groups were formed, roughly along the lines of the divisions decided upon at Chicago. The first group, directed by Robert Sears, devoted its attention to attitudinal and affective factors relevant to children's learning. The report of this committee, contained in Chapter I, deals with questions such as the following: Which attitudes and emotional states help or hinder children's learning? How do they do so? How can desirable attitudes be instilled in children?

A second work group, directed by Alfred Baldwin, was concerned with "cognitive skills." The group's report, found in Chapter II, suggests that there are general "trans-disciplinary" skills useful in diverse fields of cognitive endeavor. If there are such skills, and if they can be defined, what sorts of techniques might be used to develop them? In particular, what of the "intuitive" skills so often neglected in the classroom?

The third working party, directed by Harry Levin, was interested in what came to be called "stimulus control." "Stimulus control" refers to problems in presentation of the materials to be learned, to such problems as the structuring and sequence of curriculums. Three members of the committee prepared careful analyses of the problems involved in learning to read and in learning arithmetic. These papers appear following the group's report in Chapter III.

I have followed the policy of not editing the various papers and reports too drastically, and at times the continuity suffers. But my aim was to make available "working papers" on the subject of children's learning. The authorship of the various papers has been noted, but it goes without saying that the papers are also "joint," for they reflect the intense discussions in Chicago and Cambridge. A greatly condensed version of these papers is now in preparation under the direction of the undersigned as senior author working in close collaboration with Dr. Jacqueline Goodnow and Mrs. Blythe Clinchy.

Jerome S. Bruner

Cambridge, Mass.
December 1963

Contents

Page

FOREWORD ---------- I

PREFACE ---------- III

CHAPTER I: REPORT OF THE WORK GROUP ON ATTITUDINAL AND AFFECTIVE SKILLS

Introduction ---------- 3
Robert Sears

Problem Classification ---------- 9
Jerome Kagan

Initiating Responses ---------- 14
Paul Mussen and Clementina Kuhlman

Persistence ---------- 22
Harold Stevenson

Attitudinal and Affective Factors in Children's Approaches to Problem-Solving ---------- 28
Pauline Sears

Motivational and Attitudinal Factors in Receptivity to Learning---------- 34
Jerome Kagan

Inhibitory Factors in Attention and Mastery ---------- 40
Jerome Kagan

Process Pleasure ---------- 44
Robert Sears

Product Pleasure ---------- 47
Robert Sears

CHAPTER II: REPORT OF THE WORK GROUP ON COGNITIVE SKILLS

Cognitive Skills ---------- 53
Mary Henle

Sensitization and Activation of Cognitive Skills ---------- 64
Richard Crutchfield

Towards a Disciplined Intuition ---------- 71
Jerome Bruner and Blythe Clinchy

The Development of Intuition ---------- 84
Alfred Baldwin

Tutor and Learner ---------- 93
Rose Olver

Page

The Strategy of Instruction 98
William Kessen

Notes on Intrinsic Motivation and Intrinsic Reward in Relation to Instruction 105
Daniel Berlyne

School Arrangements 111
Blythe Clinchy

Character Education and Curriculum 117
Jerome Bruner

Curriculum: Education and Research, the Changing Pattern of Curriculum Construction 122
Lloyd Morrisett

The Curriculum Research Team 132
Jerome Bruner

CHAPTER III: REPORT OF THE WORK GROUP ON STIMULUS CONTROL

A Behavioral Approach to Instruction: General Statement of Research Problems and Strategies 137
Members of the group: Roger Brown, Margaret Donaldson, Jacqueline Goodnow, Harry Levin, Frank Restle, Patrick Suppes

The Psychology of Reading 154
Harry Levin

APPENDIX A: WORKING PAPERS

Informational Structures 167
Alfred L. Baldwin

From Codability to Coding Ability 185
Roger Brown

Theorems for a Theory of Instruction 196
Jerome S. Bruner

The Formation and Discovery of "Higher-Order" Units in Intellectual Tasks 212
Eleanor J. Gibson

Child-Rearing Antecedents of Cognitive Behavior 217
Harry Levin

Notes on a Formalism of Cognitive Operations and Task Description 223
Lloyd Morrisett

Towards a Behavioral Psychology of Mathematical Thinking 226
Patrick Suppes

The Psychology of Arithmetic 235
Patrick Suppes

APPENDIX B: NOTES ON THE PLENARY SESSIONS 243

CHAPTER I

REPORT OF THE WORK GROUP ON ATTITUDINAL AND AFFECTIVE SKILLS

INTRODUCTION

Robert Sears

The sense of crisis in contemporary education stems mainly from the extraordinary developments of science since World War II. Events of the last two decades have brought dramatically to the attention of the American people the accelerating rate of scientific discovery. Applications of findings in physics, engineering, chemistry, medicine, and to a lesser but still notable extent in the social sciences, have infused into the daily life of every citizen of Western society a broad range of scientific conceptions; to such an extent, indeed, that it is no longer possible for our society to operate effectively without a substantially greater capacity for scientific thinking on the part of average people than has heretofore been necessary. The immediate problem posed by a science which so rapidly makes itself obsolete lies in the education of American children both for problem-oriented thinking and for understanding those problems at a far more complex mathematical and scientific level than existed in the years before the last war.

In any thoughtful attack upon the improvement of education for people who must live in this modern world, one is immediately struck by the fundamental role of attitudes and motivation in the child's learning process. Children must want to learn, or they will not learn. Such a truism gives little guidance to the educator, however, for the desire to learn is itself a complexly organized property of human behavior. Motives and attitudes which support or interfere with learning may be framed broadly or they may be specific and narrow. The child who enjoys novels does not necessarily enjoy poetry. An interest in algebra is not always paralleled by an interest in geometry.

Science is essentially a matter of solving problems. To be sure, the child growing up in a scientific society such as ours must learn and be able to reproduce a vast body of knowledge. Such a body of information requires *convergent* thinking for its mastery; there are right answers, generally agreed upon. It is the duty of the school to develop this body of knowledge as a part of the repertory of each child. At the same time, however, the development of an understanding of the mechanisms by which science operates in both its pure and applied form requires a type of thinking which can be described as *divergent*. Here, whatever the current "facts" may be, the next step in developing scientific understanding is always around the corner and always demands novelty in the solution of its problems. Thus to the extent that we live in a society dependent upon applications of scientific thinking, each individual must become a master of divergent thinking—that is, problem-solving. The present report is oriented toward an analysis of attitudes, motives, and other affective aspects of personality which relate to efficient learning in the general area of problem-solving.

Generalized Response Systems

To learn how to think scientifically—that is, how to solve problems—three major response systems are required of the learner. These are qualities which must characterize him at the beginning of his learning period, continue throughout his school life, and become sufficiently stable by the end of his schooling to determine his behavior through the rest of his life. These are generalized ways of responding to problem situations:

1. A child must learn to recognize when a new situation is a problem situation; that is, he must first of all understand that problems exist and that they can be solved. He must learn how to perceive a problem and categorize it as such. A corollary of this perception is that he must have *search techniques* which he can call upon in seeking a solution. The door that won't open, the man who won't answer, the plum that can't be reached are all problems; they are also frustrations. It is essential that they be recognized as problems and that the emotional reactions of frustration be withheld until a repertory of possible responses is focused on the situation, and a search among the possible solutions is initiated.

2. The initiation of problem-solving behavior must follow at once. There is little value in the child's possessing a repertory of possible search techniques unless he takes the initiative immediately and begins to try one or another possibility. He must volunteer. He must experiment. He must seek paradigms and test them. Above all, he must do these things actively and economically. This response quality might best be summarized as *actively taking initiative*.

3. Normally, as he grows older, the child is faced with more and more difficult problems. The solution of problems for which pat answers are available becomes of little importance in his education; the mastery of new problems having difficult solutions becomes of great importance. Therefore he must respond with *persistence*. He

must learn to classify and label problems rapidly, cast them into categories having well-known classes of solutions, and analyze them into their component parts. He must keep going until the problem is solved.

These three generalized response characteristics pervade all successful problem-solving activity. In the present report, they are considered goals for the educational process. We turn first to the mediating mechanisms which are responsible for producing them. Then we shall consider under what conditions instruction can be provided to produce these mediating mechanisms or to make effective use of them in inducing tendencies toward the three desirable response qualities.

Mediating Mechanisms and Motives

There are several motives essential to the occurrence of the above responses. Six of them have been isolated in our discussion and will be considered at some length in the sections that follow:

1. Motivation for achievement is a coarse category which yields, on refinement, a number of elements. Some motivation is dependent on *extrinsic* incentives. For example, a child may perform well in problem situations to secure the approval and affection of his parents, teachers, or peers. Or he may achieve simply to get the problem solved and out of his way. In other instances, however, motivation toward achievement seems *intrinsic* to the problem itself and gradually becomes the basis for the child's learning and his continuing performance as a problem solver. Since the gradual induction to intrinsic motivation for achievement is an important element in the educational process, the problem of intrinsic versus extrinsic gratification will be given considerable attention.

2. Expectation of success is also important. A child must have a sense of confidence in his own abilities and a set of realistic goals for his own performance that will enable him to recognize when he has been successful and when he has not. Conversely, expectation of failure sharply inhibits efforts at problem-solving. One must recognize that the process of problem-solving demands both repeated effort and the development of divergent ways of approaching problems. Failure is inevitable, and ways must be found to retain the advantages of temporary failure without being paralyzed by the inhibitory effects of continuing failure.

3. The child must have a critical and reflective attitude towards his own performance. He must be able to treat the outcome of his efforts at problem solving in a realistic way. He must know when he is succeeding and when he is not. He must learn to avoid the false satis-

faction of fantasy solutions. He must have an effective system of self-evaluation and self-guidance.

4. The process of identification with an appropriate model, be it parent, teacher, or peer, is a mechanism of great importance. Through identification with a positive model, a child can learn to value intellectual performance and the solving of problems; a negative model can have vastly harmful effects upon the educational process.

5. The child's perception of the *role appropriateness* of intellectual activities is important. The lower-class child faced with intellectual tasks not relevant to anything he will ever do in his later life is in the position of learning useless information. The girl pressed to learn behavior she conceives to be masculine is engaged in a self-defeating process. Different types of learning experiences must be carefully evaluated in order to maximize their usefulness in the learning process.

6. Generalized inhibitions arise from fear of ridicule or loss of status. The anxieties (and the defenses against them) which stem from punishment in the home and school can have a crippling effect on the child's attempts to develop initiative and persistence in problem-solving. The origins and possible cures for these inhibitions must be examined. Our present concern, of course, is to create educational conditions which will prevent them from developing in the first place.

These various motives and mediating mechanisms are by no means simple to analyze or manipulate. As possible sources of both interference and facilitation, however, they must be investigated with care, and techniques discovered to increase positive motives and eliminate negative ones. This question too will be dealt with in the sections that follow.

Instructional Variables

In any discussion of devices by which the mediating mechanisms and their resulting response qualities can be developed, one must attend to the educational process itself. We face one overwhelming fact. It is impossible for a single teacher to be assigned to every child. We must not make the mistake of overemphasizing the importance of individual differences in children's behavior and the gains to be achieved by teachers attending primarily to these differences, for a teacher faced with 30 youngsters can devote little time to individual diagnosis and therapy. In considering instructional procedures to increase the effectiveness of teaching problem solving, we must concentrate on teaching methods of two kinds, both directed away from the utopian one-one relation between teacher and child.

First, we would urge the development of self-instruction devises that children may use in the classroom at their own pace. These must be devised in such a way that a child can select his own problems, secure the necessary guidance and stimulation, and find reward —all from the instruments themselves.

Second, we believe it is important to devise research projects for discovering generalized principles that apply to the overall teaching process rather than to individual interactions between teacher and child. For example, the effects of group rather than individual reward for particular responses have proved to be conducive to the development of a good self-concept in children of above-average intelligence, though group punishment has a poor effect in this respect. Principles of this sort could give the teacher a general approach to her teaching, saving her the necessity of developing a unique approach to each of 30 children.

In general we are inclined to believe that much profitable research in the field of instructional variables lies in astute behavioral analysis of teaching methods already in use, methods which have been demonstrated effective in producing those very learning outcomes with which we are concerned here.

Research Orientation

Finally, the report will concentrate on the directions in which the greatest profit from research on methods of teaching seems to us to lie. There are three major problems that need more detailed answers than are now available.

1. A careful analysis should be made of the resources with which children enter school. The behavioral qualities with which we are concerned here are not developed *ex nihile* in kindergarten or first grade. The 5-year-old child already has substantial action systems relevant to problem-solving, systems that have been developed in his relations with his parents, siblings, and peers. The nature of these systems is of considerable importance to the teacher of kindergarten and first grade, because the child's initial repertory determines the degree to which the teacher can effectively introduce new learning.

2. We must consider also the extent to which the various behavioral qualities and mediating mechanisms can be *trained* in the grades from kindergarten through six. We have assumed that learning experiences can be provided that will, over a period of years, improve these responses and mechanisms. While there are already some research findings supporting this supposition, more elaborate and detailed examination of the limits of training, and effective methods for it, must be undertaken.

3. Finally, the degree of transfer from training procedures to other learning situations must be studied. We do not yet know the scope of transfer potentially available, nor do we know the conditions under which transfer is most likely to occur. We need a thoroughgoing search for the limits of the transfer process and the conditions which are optimal for it.

PROBLEM CLASSIFICATION

Jerome Kagan

Classification of a problem involves recognition of a terminal state to be reached and an awareness that it has not yet been reached. The recognition phase may or may not include an ikonic or symbolic representation of the sought-after terminal state or answer. Indeed, in most cases, the individual does not have an image of what the answer should be, merely acknowledging that an answer is required. If the student has a symbolic representation of the answer or its approximation, he then has a reference to consult during and after the problem-solving activity. Such a consultation furnishes him with feedback information that acts as a cue to guide him towards a solution, as a signal when the problem is solved, and as a basis for assessing the probability that the final answer is correct. Thus, it seems desirable to teach the child to estimate the range within which the answer lies; or, in cases where this is not feasible, the range might be given to him directly.

There are several common errors in problem classification: (a) omission of a critical piece of information that is objectively present in the problem, (b) addition of information that is not part of the problem, (c) misunderstanding or miscomprehension of the information in the problem, (d) acceptance of an irrelevant piece of information as relevant. These four anomalies all assume that the subject's cognitive skills allow him to process the informational mode of the problem (that is, the child can read, the child can see, the child can hear, etc.). We shall ignore for the moment the difficulties arising from the child's inability to process the problem in its raw informational form.

The accuracy with which problems are classified is a function of the following predisposing factors:

1. The child's motivation to obtain immediate or delayed approval or nurturance for correct classification.
2. His expectancy of failure.
3. Inhibitory factors (e.g., expectation that successful problem solving will lead to goal states that are not desired by the child).
4. Identification with role models who value intellectual activity.

5. The degree of reflection and evaluation that accompanies the classification.
6. The appropriateness of the problem in terms of sex and age.

The last two factors are particularly relevant for classification.

Reflection-Impulsivity and Problem Classification

There is an important dimension of individual difference which can be labeled reflection-impulsivity. It deals with the degree to which the child actively reflects upon alternative classifications or hypotheses in situations where multiple answers or hypotheses are simultaneously available to him. Although there are several ways of measuring this variable, the one used most often in our laboratory involves a procedure which has been called the Design Recall Test.

In this test the child is presented with a geometric design and told to study it. After 5 seconds the stimulus is removed, but its image must be retained in the child's mind for 15 seconds. Then an array of 8 to 10 similar stimuli is presented, only 1 of which is identical to the standard (the originally studied design). The child's task is to locate the stimulus identical to the standard.

The reflective child first scans all the possibilities before offering an answer. The impulsive child accepts the first hypothesis that occurs to him. Thus reaction-time and errors are the operational indices of reflection-impulsivity. Using error scores on this test as an index of impulsivity we turn up the following generalizations as appropriate. It appears that with age children become more reflective and more concerned with the validity of their answers. Where the task is to interpret ambiguous information, reflective children tend to delay longer than impulsive children. There tends to be greater variability in impulsivity for boys than for girls. The correlates of this dimension appear to be different for the sexes. For the girls, rejection of traditional feminine sex-type activities is correlated with reflection, but this dimension is independent of reflection among boys. Thus the girl who has adopted traditional feminine activities is likely to be impulsive in initially classifying stimuli. This correlation makes sense, because we assume that one basis for an impulsive orientation is low motivation, or low involvement in the problem. Since girls who adopt the traditional feminine identification view intellectual tasks as less appropriate and less desirable for them, it may be that they care less about the quality or the validity of their hypotheses and therefore classify problem situations more impulsively. Research at the Fels Institute indicates that young girls who reject a traditional feminine identification are more likely to come from well-educated mothers and more likely to be involved in school achievement during the elementary, high school, and college years. Even when one controls for social class and education of parents, there is an inverse relationship between degree of acceptance of feminine sex-typing and achievement in school and involvement in intellectual mastery.

It is interesting that there is no strong relationship between degree of sexual identification and the reflection-impulsivity dimension for boys. On the other hand, a hyperkinetic disposition—which emerges at about age 3 or 4 years—seems to be moderately predictive of an impulsive classificatory approach in the school-age and preadolescent boy, but not in the girl. Longitudinal investigations of children from the Fels Research Institute's population indicate that boys who are restless and show task-irrelevant hyperactivity during the nursery school years are more likely to be impulsive on classification tests than children who do not display this tendency. Thus one might conjecture that the beta-weightings for variables determining impulsivity are different for the sexes, with early hyperkinesis more relevant for boys and rejection of sex-typing more relevant for girls.

Modifiability of a Reflective-Impulsive Attitude

It seems reasonable to expect that children who show moderate predispositions toward reflective or impulsive behavior could be trained to change these predispositions when appropriate. In one experiment the simple instruction to think about one's answer was effectively increased reflectivity. It might be easier to train an impulsive child to be moderately reflective than to train the reflective child to become impulsive. Some simple teaching procedures could include such things as instructing the child to proliferate hypotheses regardless of his confidence in them; or, for tasks where reflection is an appropriate response, requiring the child not to offer his first hypothesis but to think of alternatives and evaluate each by stating his faith in his possible answers.

Relationship of Visual Analysis to Classification of Problems

There are many problem situations in which the material to be worked upon is presented visually. In such situations the degree to which the child tends to analyze the stimulus visually becomes important in determining the kinds of hypotheses and problem-solving sequences he follows. We have called this variable "fractionation." It is a behavioral predisposition which can be measured in several ways. One method is to test the degree to which the child visually fractionates a stimulus during learning. In this procedure the child is taught a series of nonsense syllables associated with four or five different geometric designs, each made up of various components.

After reaching criterion, the child is shown the separate component parts of the original stimuli and asked to apply the correct nonsense syllable. The child who fractionates the original stimulus will have more correct responses than the child whose general tendency is moderately correlated with the reflection dimension (r is usually between .30 and .40), and that boys have much higher scores than girls.

Relation of Predisposing Motives and Attitudes to Analysis

Our finding that boys fractionate more than girls is supported by the work of other investigators (Witkin, for example). Though reasons for this difference are not completely obvious, several interpretations come to mind. One possibility is that the stimulus materials normally used in these tests, which are geometric, may be viewed by girls as relatively masculine in character, but we doubt that this is a major determinant of the phenomenon. The second possibility is that girls are less likely than boys to make the quick, saccadic eye movements that should facilitate visual analysis. Detailed studies of the eye-movement patterns of boys and girls would furnish evidence relevant to this hypothesis. A third possibility is that the toys boys play with during the preschool and early school years (e.g.., trucks and mechanical gadgets) train them to attend to detail, and that this predisposes them to fractionate. Finally, the boy may have a set in laboratory tests that the examiner is out to trick him. The differential play behavior of young girls and boys suggests that boys are more likely than girls to set verbal and physical traps for each other. This experience should lead the boy to distrust the obvious and the manifest and to attend to the hidden detail.

Since parents and parent surrogates are not likely to reward analysis directly, this disposition may well be a function of more subtle experiential variables. Since analysis is relatively independent of IQ (the correlation is in the twenties), it is not a concomitant of well-developed verbal skill. Investigations into the relationships between types of play experience and analytic tendency should be undertaken.

Relation of Reflection and Analysis to Reading Progress

Reflection and analysis should be intimately related to speed and efficiency of learning to read—a primary task of the early school years. To discriminate between a *p* and a *b*, for example, requires *reflection over alternative hypotheses* and *visual analysis*. The decision as to what "bad" represents is an instance of the most frequently occurring problem a 6- or 7-year-old must solve in the school situation. Let us analyze this problem in some detail. For the child the problem is to discover the meaning of the word. His involvement in the material being read (that is, his expectation that nurturance is contingent upon reading mastery, his identification with models who value mastery) will influence the persistence with which he will pursue a problem, and the likelihood that he will proliferate hypotheses. The probability of *successful* solution, however, is determined by the child's tendency to analyze the orthographic form and the degree to which he reflects over the possible accuracy of his answer. Thus we delineate two distinct processes in problem solving. One involves the degree of involvement in the problem, a variable which determines the likelihood of *proliferating* hypotheses and persisting until solution. This behavior is under the control of the several motivational and attitude variables specified earlier. The other class of responses involves the specific habits of reflection over the differential validity of alternatives, and visual analysis. These latter tendencies should be amenable to training in the nursery and early school years. Receptivity to this training probably depends in large measure on the motivational variables that determine involvement. To alter these tendencies, one must maximize identification between teacher and child for the young child, and establish a nurturant relation that makes him want to master tasks in order to maintain the nurturant tie.

INITIATING RESPONSES

Paul Mussen and Clementina Kuhlman

Initiating responses consist of active participation and interest in the task at hand, whether that task be the solution of a problem, the mastery of some subject matter, or the creation of an idea or product. Some forms in which such participation and interest may be manifested are concentrating attention, effort, and energy on a task; bringing together relevant skills and knowledge and, on the basis of these, volunteering appropriate information and proliferating ideas; analyzing and exploring; and asking questions, proposing solutions, and challenging ideas and statements. The concepts of curiosity, exploration, set, attention, tolerance of ambiguity, and orienting responses are all related to initiating behavior. Attitudes and approaches opposed to initiating behavior may be labeled "passive" receptive and are characterized by lack of involvement: watching and listening rather than participating; a kind of minimal compliance with instructions; unthinking conformity; and doing a task "just to get it done." In extreme forms the absence of initiating behavior may reflect feelings of impotence in the face of problems, extreme fear of or anxiety about failure, a tendency to be easily overwhelmed, a "devil-may-care" attitude, or withdrawal even from problems that could be solved with relatively little difficulty.

Since obviously the child can take maximal advantage of educational opportunities only if he has developed strong tendencies to initiate responses, the development of such responses becomes an issue for a theory of instruction. In examining the evolution and strengthening of initiating response, one must consider (1) antecedents in child-rearing that predispose a child toward initiating behavior or that inhibit it, and (2) instructional techniques that can be used to maximize the growth of such behavior in the classroom. In the following sections we shall discuss variables that determine the occurrence and stabilization of initiating behavior, outlining for each variable its ramifications in child-rearing and in instructional techniques.

Motivation and Identification

Two types of reinforcement seem important in determining the child's propensity to perform initiating behaviors: (1) the direct reinforcement by parents or surrogates of initiating-type behaviors and (2) the indirect reinforcements provided by behaving like an emulated model (identification). These will be considered in turn.

Motivation

It seems quite probable that early parental handling of a child's drives toward curiosity and independence—which are strong during the second and third years of life—will have significant and enduring impacts on the development of initiating attitudes and responses. If the child's early efforts toward independence are met with encouragement and reward, independent behavior is likely to be strengthened and to generalize to many situations, including learning situations outside the home. In contrast, the child whose parents are not interested in his ideas and opinions, who is taught to be "seen and not heard," gets little reinforcement for initiative. Analogously, there are wide variations in the extent to which the exploratory behavior and curiosity of the young child are rewarded or punished. From the data available at present, it appears that the encouragement of behavior related to initiating responses—independence, curiosity, spontaneity, creativity—is most likely to occur in warm, permissive homes where the child's individuality is respected and allowed to flourish. Kagan has shown that independence in early childhood (presumably the product of reward for independent behavior) is related to subsequent school success; and need achievement, which is highly correlated with academic success, is significantly related to early training for independent behavior.

Identification

The role of the parent as an identification model is also of crucial importance in the development of motives leading to initiating responses. If the parent is active in his approach to problems, curious about many things, interested in and inquisitive about the world around him, the child is also likely to acquire such characteristics. If, on the other hand, the parent is passive-receptive or derogates intellectual inquiry, the child is not so likely to acquire habits of initiating behavior.

It is still possible, however, that as the child grows older, he may find new identification figures outside the home; he may find, in teachers, other adults, or peers, a model for the development of initiating behavior.

Role of the School

While the child has undoubtedly developed some notion of his own competence and some predisposition to assume an active or passive relationship toward learning before he enters school, his school experiences, particularly during the earliest years, may bring significant modifications. It is our contention that, where the tendency to initiate behavior is weak, it is essential to stimulate this behavior early in the school career; the longer the child maintains a passive attitude toward learning, the more difficult it will be to develop initiating responses.

To accomplish this, the teacher in the primary grades must be highly observant and flexible—using highly individualized approaches—in her responses to children's initiating behavior. If the child arrives at school already predisposed to assume an active and inquiring position in relation to learning, the teacher's task is to put seeds in fertile ground so that the propensity toward initiating behavior will generalize into many school activities. She must convey to the child that school is a place where interesting problems are posed, where questions and exploration are encouraged, and where an active approach to new tasks can be satisfying. In part the effectiveness of this message will depend on her initial behavior in relation to the child's initiating responses, and in part it will depend upon providing opportunities for the child to generalize his initiating predispositions. She might accomplish her aim by "enriching" classroom activities to include novel or unusual tasks and problems of inherent interest to children, encouraging them to use their initiating responses in these new situations. Examples of such tasks are appropriate puzzles and practical daily problems (for example, how can we fix this broken pencil sharpener?). Our knowledge of the spontaneous interests of children at different ages is inadequate; there is need for further research on this problem. In addition, systematic information could be provided by observational studies of teachers known to be adept at creating curiosity and an active approach to learning and an attempt to describe in detail the exact techniques they ues.

Where a child's predispositions toward making initiating responses are weak, the instructional problems are much more complex. There, the teacher's first task is to provide opportunities for the child to make some initiating responses—to get the responses going—so that they can be rewarded. The problem is to find tasks that stimulate the child's curiosity, even, where helpful, through maternal interviews about the child's spontaneously expressed interests. The teacher must, then, be flexible and creative in devising situations that give the child an opportunity to ask questions and to proliferate and try out ideas, so that she can reinforce such behavior. Shy, timid children are more likely to make initiating responses in situations where they choose the task or the problem themselves and where they perform privately rather than in public. It might be argued that such children are more likely to show initiative, at least in early school years, in auto-instructional rather than classroom settings. For children whose primary inhibitions appear to involve language, nonverbal tasks are more likely to elicit initiating behavior.

The teacher's first rewards should be powerful though appropriate, often taking a nurturant form. Questioning and curiosity should never be punished, for extinguishing of the child's early initiating responses must be avoided at all costs.

At the outset of schooling it seems likely that anxiety and confused expectations about the school situation may inhibit initiative. Therefore, any procedures that lead the child to believe that school is a free situation, permitting and even encouraging initiative, will improve the conditions for development of initiating responses. The best strategy may be to allow the child to attend school alone or with a few other children before the formal opening of school, so that he can get acquainted with the teacher's expectations in the security of a small group.

In all of her contacts with the class the teacher provides a potential model for identification. To provide a model for initiative she should be active in her own approach to problems, showing curiosity about things and interest in the world around. She can demonstrate in her own behavior how one asks questions, how one explores new problems, and how one develops possible solutions or problem-solving routes. Most important, by her own willingness to pose questions to which she may not know the answer, she demonstrates to the child the fact that knowing the right answer may not be so important as being willing to ask and to find out.

Concern About Failure

The child who is preoccupied with the possibility of failing will inhibit his initiating responses even though he is strongly motivated to master learning situations. A child paralyzed by fear of failure will not initiate responses; he will not really face a problem situation, or if he does face it he will feel helpless with it. In time he may lapse into a passive, or even negativistic, attitude toward the learning situations.

As a result of punishment for early attempts to explore and act independently or of unrealistic expectations by the parents, the child may see himself as inadequate, lacking the ability to succeed and to achieve important goals. For such a child every initiating response becomes a test of his self-image and competence. This state of affairs is perpetuated in a classroom where the only acceptable answer is the correct answer, and where the child is rewarded only for asking good questions or giving good answers.

While it is at least theoretically possible to differentiate between lack of motivation to perform initiating responses and fear of failure if such responses are attempted, the overt behavioral manifestations of the two are essentially the same. Therefore, in handling children who are extremely fearful of failure, the teacher can probably make effective use of the same kinds of techniques discussed under motivation. That is, in the early stages any response, regardless of quality, should be reinforced by the teacher with an eye to helping the child feel freer. As the child feels more comfortable and finds he is successful in getting the teacher's support, he will ask more questions. Partly through experience and partly through guidance by the teacher, the child will eventually begin to learn techniques for asking and for analyzing and can begin to judge the adequacy of his own responses. The teacher can help the child follow through on a question he asks until it has been shaped into an adequate one. As these experiences of adequacy increase, the child should be less and less inhibited by a fear of failure; rather, he should begin to feel, quite realistically, that he can perform competently.

The fearful child may learn in addition that the use of skillful initiating responses (hypothesis formation and the asking of questions about possible outcomes of proposals) can help him *avoid* failure. Questions and hypotheses are unlikely in themselves to lead to frustration; rather, the optimal use of questions, hypotheses, and VTE before leaping to conclusions or into action prematurely may reduce or eliminate subsequent frustrations.

In addition to the matter of alleviating the child's fear of failure, there is a more general problem of learning to tolerate failure to the extent that it is necessary in the educational process. While it is important to reinforce the initiating aspects of problem-solving behavior, one must avoid the reinforcement of wrong responses. Experiences of failure must be paced carefully for each child. Perhaps in the early school years punishment for failure should be avoided as much as possible, and experiences of success should be maximized. Clearly we need research on the optimal distribution of success and failure in problem-solving sequences at different ages.

Self-Guidance and Self-Criticism

While active, question-asking, hypothesis-forming approaches and explorations should be strongly encouraged in school—especially with children who are inhibited in this respect, withdrawn, or extremely passive—the child must learn that all questions are not equally relevant or productive of information. Some questions are too diffuse or general; the information they elicit is too vague to be useful. In other cases, they entail a considerable delay before the answer is obtained. Indeed, not all questions are answerable; the child must learn to tolerate ambiguity and to use "not knowing" as an incentive.

Once the child has developed an active response-initiating approach, it seems desirable to "shape for excellence," to perfect exploratory, analytic, information-seeking skills, and to help the child learn to guide himself in his initiating behavior, to criticize and evaluate his questions, ideas and hypotheses.

The sensitive and alert teacher can foster such learning in several ways. By guiding the child's questioning, she can show him explicitly, through reinforcement, what kinds of questions "pay off,"—that is, lead to satisfactory solutions—and what kinds are likely to lead to dead ends. Although the teacher must be careful to reinforce questions and the curiosity behind them, she must not answer questions prematurely, for this may lead to a shutting off of the flow of questions.

At times the teacher should probably reward and encourage self-critical evaluative questions directly. At other times she should assist the child to rephrase, to focus his questions on relevant aspects of the problem, and to break down or fractionate general questions into component parts. In short, the teacher's guidance is necessary to shape active but inadequate curiosity and question-asking into high-level skills.

While our previous discussion of failure stressed its inhibitory effects, experience of failure can have positive results, strengthening the motivation to initiate and persist in a task. Often a child will benefit a great deal from being allowed to follow out the consequences of his questions and hypotheses and to fail, so that he may realize the inadequacy of some of his questions and learn to ask better ones. For example, in solving a puzzle box or class problem, the teacher might encourage a child actually to test out his hypothesis, allowing him to see (and suffer) the consequences of his poor leads. Presumably this failure would foster a self-critical attitude and result in more VTE, more implicit trying out of questions subsequently. Research data indicate that these outcomes are more likely to occur among highly intelligent children than among duller ones.

It is our contention that the teacher must use a highly individualized approach in handling the child's early questions. Thus, responses to the questions of an impulsive child must be different from those to questions that show evidence of reflection. The impulsive child must be taught to delay his actions, either by further practice in self-criticism, expressions of criticism by teachers or peers, or actual experiences with the unfortunate consequences of some impulsive actions.

In skillful teaching, the child's "initiating" responses are evaluated realistically. No matter how farfetched or irrelevant the child's first questions seem, the teacher will not ridicule or belittle them, for if she does, she runs the risk of inhibiting his subsequent participation in school activities. On the other hand, by skillful guidance she can teach the child—perhaps with the aid of other children in the class—to break down broad, unanswerable questions or problems into smaller, soluble sub-questions or sub-problems. Successful solution of these sub-questions not only stimulates further questions but also provides a kind of reserve of confidence in one's ability to solve problems. Consequently, the child will not feel severely frustrated when he asks questions that cannot be answered immediately, either because of his own intellectual limitations or because answers simply are not available.

The gradual realization of such limitations will serve to reduce the child's feelings of omnipotence. At the same time he will become more realistic, but reasonably self-assured, in his approach to intellectual problems. It follows that his level of aspiration will be a realistic one; that is, he will learn that effective mastery of complex problems usually involves the formulation and solution of a series of smaller, interrelated problems.

While the child's skillful and efficient use of questioning may be developed primarily through his contact with his teacher, other techniques can also be useful. In the lower grades, children may be told stories in which reflective, question-asking, reasoned approaches to a problem lead to better results than unthinking, impulsive actions. Discussion of the stories may lead to the development of a generalization about these actions. In later school years, classmates' evaluations of the child's questions may help to sharpen his skill and also help him to perceive more of the implications of his hypotheses and plans. This might be particularly true during the adolescent period when peer pressures are likely to have strong influences on the child.

Appropriateness of Materials

Predispositions to making initiating responses vary with a number of personality and social factors. Middle-class children, coming from more verbally stimulating environments and less authoritarian family settings, are more likely than lower-class children to make initiating responses frequently and to evaluate them critically. Moreover, there are sex differences in interest in schoolwork and consequently in initiating responses. At the early ages, according to

Kagan's data, schoolwork is perceived as feminine. Girls are more interested and probably make more initiative responses in school than boys, although boys are probably more involved, more competent, and show more initiative in some areas such as arithmetic. This pattern of interests and motivations changes with age, girls becoming less involved in schoolwork during adolescence, perhaps because the intellectual achievement is conceived as being incompatible with the feminine role.

To elicit initiating responses requires the use of materials that have relevance and interest for lower-class children as well as those of the middle class; it requires also the inclusion of more material related to both male and female roles. As noted earlier, there is need for further normative research on age, sex, and social class differences in interest patterns. The results of such systematic study may be directly applicable to the selection of appropriate materials for classroom use. Boys' interest in school might be stimulated if there were more men teachers in the lower grades and if more use were made of visiting lecturers such as policemen, firemen, or doctors.

There is also urgent need for further research in age trends in the use of language and in intellectual development in general. Findings may be directly applicable to the problem of the range and level of intellectual challenge that the teacher can reasonably present to her class in her attempts to stimulate interest and initiating responses. Such data can also serve to define the limits of the child's intellectual skills and comprehension so that the teacher can avoid the extremes both of "talking down" and of overstimulation (for example, encouraging questions and curiosity which could be satisfied only if the child were more sophisticated).

PERSISTENCE

Harold Stevenson

A child's success in school depends not only upon his adopting a problem-solving attitude and initiating responses, but also upon his persisting in making responses relevant for the solution of the task. A general tendency for persistence could of course easily become non-utilitarian. The child must persist only when the responses are leading to progress in the solution of a problem; persistence in inappropriate responses leads to stereotype or perseveration. The aim, therefore, is to provide conditions which will increase the child's tendencies to persist in responses leading to the goal and to vary these responses when some of them prove to be inappropriate or insufficient.

Background Conditions for Developing Persistence

In most learning situations a child gains little by persisting in a task for which his responses are inappropriate, his ability inadequate, or his information insufficient. A child will try, if at first he didn't succeed, only if it is clear to him that by continuing to try he will eventually be able to master the problem. A teacher interested in developing persistence in children must first provide problems in which persistence will have positive consequences for the child.

The major task is not to *develop* persistence but to maintain it as the child moves from tasks he spontaneously selects to those imposed upon him by the teacher. When a young child is not persisting, we must ask why the problem is not meaningful to him. The problems which the child himself selects are usually ones which he knows he can solve or is interested in learning how to solve. Protracted and intense persistence is common in children. The baby attempting repeatedly to remove his father's glasses, the 6-year-old setting forth once more on the bicycle from which he has just fallen—this is the kind of persistence we should like to develop in the classroom.

Preparation for persistence—or for non-persistence—begins at home. Many middle-class children move with ease into the school situation, for they have had experience at home in following directions, listening to their parents, and answering questions. Lower-class children, on the other hand, often have very little interaction with adults, and the interaction that they do have is often in the form of carrying out tasks defined largely by parental authority.

Personality Characteristics Relevant for the Development of Persistence

There are a number of personality characteristics which inhibit persistence. Anxious children find it difficult to persist in any task, because their behavior is disrupted by the intrusion of other responses derived from their anxiety, such as hyperactivity, hyperemotionality, and intrusive thoughts and fantasies. Thus a child with harshly evaluative parents may expect similar reactions from the teacher and may not persist in making relevant responses because of the anxiety which is aroused. The highly dependent child finds it hard to persist because of his inordinate need for definition, structuring, and response from the teacher. Highly inhibited children are disturbed by being in a situation where they must respond at all. Personality characteristics such as these have long histories, and it is doubtful if the teacher can attempt to eliminate them. From such groups of children little can be expected at first, and only with slow and sensitive guidance can the effects of the early experience which leads to these forms of behavior be decreased so that the child can function more effectively in school.

The Modification of Persistence

It is clear from research with children that the tendency to persist can be increased with appropriate training. An increase appears to be possible when (a) the child has a relationship with an adult so close that pleasing him can be satisfying; (b) the problems are presented in steps of difficulty so that the child may, during the early stages of training, experience success relatively easily; and (c) the problems are interesting to the child. The most common block to persistence is frustration and the disruptive and disintegrative behavior produced by frustration. Training procedures should aim, therefore, to reduce frustration by attempting to get the child to see that the problems can be solved and by giving him techniques for handling frustration so that its negative effects are reduced.

Task Variables in Developing Persistence

Careful manipulation of the types of tasks that the child is asked to perform may help to increase his willingness to persist. In most curriculum materials little attention is paid to two important psychological processes, habituation and satiation, both of which are common bases for decreases in persistence. Habituation refers to the decreased effectiveness of a stimulus in eliciting a response when the stimulus is presented repeatedly. Satiation refers to the decreased motivation to respond following repetitive responding with the same outcome. Persistence may be increased by varying the stimuli, utilizing different responses, and by varying the consequences of response. It is not surprising that a workbook of problems, all presented in a similar manner, all requiring the same form of response, and all leading to a simple answer, may reduce children's tendencies to persist. How many times are children surprised by what they have produced? How many of the materials are vivid and exciting? How often are forms of response other than printing and writing employed?

The use of varied materials, responses, and consequences should not, however, be allowed to result in increased complexity of problems. It is doubtful that increasing the complexity of problems will necessarily increase persistence on subsequent presentation of similar or identical problems. The readiness to repeat a response appears to vary negatively with the amount of effort or time required to reach the solution of a problem. In an interesting study of persistence, Wolfe used tasks ranging from dropping beads into an enclosed container to constructing elaborate models with Tinker-toys. Children were less willing to continue responding when they were asked to repeat the construction of the model than when they were asked to repeat the simpler form of response. Seeing that they could make the model once was enough; there was little to be accomplished by going through all the work again. Requiring children to solve "practical" problems involving a series of steps may reduce persistence, then, more than the presentation of simple, but apparently duller problems.

The Reinforcement of Persistence

Persistence, like any form of behavior, appears to depend upon the consequences it produces. The most frequent outcomes for satisfactory performance in school are praise from the teacher, grades, and other tangible forms of reinforcement. The form of reinforcement in increasing response varies, depending upon the child's socioeconomic status, age, and other variables.

In discussing the role of reinforcement on persistence in school, we are handicapped by the fact that there is so little in the literature about this subject except for some old studies on praise and criticism of general classroom performance. There is, however, a large literature on the effects of reinforcement on persistence in laboratory studies, though it must be recognized that the tasks used in these studies have all been relatively short, the problems relatively simple, and the situations artificial. Nevertheless, the results may be appropriate to the discussion of persistence in the daily school routine; at the least, they provide problems that could be readily investigated in the practical setting.

Types of Reinforcers and Social Class

Different types of reinforcers have been used in studies involving learning to discriminate among geometric forms and in studies involving the insertion of marbles into appropriate holes of a formboard. Terrell *et al.*, using candy as a tangible reinforcer and a signal light as a symbolic reinforcer, found that there were no significant differences in the learning of middle-class children as a function of the type of reinforcement. In contrast, tangible reinforcement was found to be more effective with lower-class children. When social reinforcement was used by Zigler in the sorting task, further differences in performance according to the child's socioeconomic status occurred. The lower-class child would rather be approved than right, while the opposite is true of the middle-class child. Middle-class children persisted longer in performing the simple motor response when they were told that they were "right" or "correct," while lower-class children persisted longer when the experimenter responded to their performance by saying "good" or "fine."

The Effects of Social Deprivation

A study has recently been completed in which children with varying degrees of social deprivation, as indicated by ratings of their case histories, were tested on the sorting task described above. A negative relationship was found between the effectiveness of social reinforcement and the degree of deprivation experienced by the child. These results, if they have any general validity, lead to an interesting paradox: it is often the deprived children who give the teacher the greatest difficulty. Yet, if these children are more affected by the support offered from an adult, one would expect that they would be the most malleable. Perhaps the difficulties that teachers have with such children are due to the fact that too many and too complex tasks are presented too early. It would be interesting to know whether persistence in such children could be increased if fewer and simpler tasks were presented during their early months, or even years, in school. With such tasks the remarkable effect of an adult's supportive comments upon persistence might be found in school as well as in laboratory situations.

Reinforcement and Age

Studies of preferences for reinforcers among children of different ages indicate a general transition from a preference for tangible to social and symbolic forms of reward as age increases. Witryol found, for example, that as children grew older they more and more preferred such consequences to their behavior as "being right" or "being told they were right or doing well" to such tangible objects as candy.

Studies indicate that the effectiveness of social reinforcement in increasing persistence or rate of response is positively correlated with the child's level of intelligence until about the ninth year. By this age it appears that the child is providing his own reinforcement—in seeing that he is doing well, that he is progressing, or that he has mastered the task. After the first years of elementary school it appears, then, that much of the reinforcement, except in difficult or extensive problems, may come from the child himself. In fact, by the time the child is in junior high school, persistence may be increased more by negative comments indicating to him that he is not doing satisfactorily than by supportive comments.

The Relationship of Sex and the Effects of Social Reinforcement

One of the most subtle variables influencing the degree to which praise or other forms of support may be effective in increasing performance is the sex of the adult in relation to the sex of the child. Generally, of course, there are striking differences among adults of either sex in the degree to which they are effective in modifying children's behavior by providing a supportive reaction to the child's responses. Further, particular children are more responsive to particular adults than are other children. In spite of these strong individual differences, there seem to be certain general effects on performance, depending upon the age and sex of the child, and the sex of the adult. Preschool children are only minimally affected by receiving a supportive response from a male experimenter in a sorting task such as that described. If the experimenter is a woman, she has little effect on the performance of boys, but has a strong facilitating effect on the performance of girls. This, of course, is in line with the view that the woman teacher acts as a model for identification in the preschool girl. The effects change with age, however, and by the early elementary years studies indicate that men may be more effective in increasing the performance of girls than of boys and that women may be more effective with boys than with girls. Translated into the classroom situation, these data mean that the child should be placed with a teacher appropriate to him in sex and other personality characteristics. There are, of course, immense problems in such a proposal. But it may be useful to consider providing elementary children with a greater variety of teachers at each grade level. With a greater number of teachers, including both men and women, the probability of a child's having a teacher who is appropriate for him is increased. The critical question that remains is whether response tendencies such as persistence, which may be developed through a satisfying relationship between the child and a particular teacher, will generalize to other teachers.

The Use of Reinforcement

The effectiveness of the teacher in providing any form of reinforcement depends upon whether the teacher is sensitive to the degree of reinforcement demanded by each child and whether she responds at the proper times. One child may require a low frequency of response and only at the end of the task, whereas another may require a high frequency and at the conclusion of each phase of solution.

Instruction for Persistence

Verbal response may be effective in developing and maintaining persistence but ineffective in initiating it. Verbal communication is the primary mode of initiating response in adults' interactions with children. There are numerous studies indicating that differences in instruction do not have a strong effect in producing different forms of response in young children. For example, behavior in experimental tasks does not differ when young children are told either that a problem is solvable or that it is not solvable. Probably, then, verbal instructions about persistence should be minimized, and problems should be structured so that the consequences of persisting or terminating responses are clear to the child. The use of sub-tasks with clear consequents and the structuring of tasks with a clear terminus are desirable. The importance of clarity of goals and structuring of tasks cannot be overemphasized.

Little persistence, many questions, and much irrelevant behavior are frequently due to the child's failure to understand just what he is supposed to do. Early studies of social groups indicate that, unless the children are aware of the product to be achieved and the steps necessary for its achievement, relevant responses persist only when the authoritarian leader maintains control of the group. Persistence is little impaired, however, when the leader leaves a group that knows the long-range goal and the steps leading to it.

ATTITUDINAL AND AFFECTIVE FACTORS IN CHILDREN'S APPROACHES TO PROBLEM-SOLVING

Pauline Sears

Establishment of Search Techniques for Situations Perceived as Problems

This section is concerned with children's attitudes toward their own problem-solving skills. It is assumed that an important part of the child's self-image is the degree to which he expects to succeed in solving problems in and outside of school and in satisfying other needs, such as his need for acceptance by significant other people, and his need to identify with chosen models. The energy he will employ in addressing himself to problem situations appears to be related to such expectations. Also involved in his initial approaches, as well as in his persistence at the problem, are the tactics employed *by the teacher or parent in guiding him toward* appropriate problems and his perception of the nature and difficulty of the problem. *Problems which will engage a child's endeavor must hold promise of success at something which he values as a result of his previous experience in his own particular subculture.*

This proposition suggests, first, an *analysis* of the *problem situations* usually found in public school classrooms at kindergarten and first-grade levels, when attitudes toward the self as a problem-solver are probably most malleable. Second, an analysis is required of the *resources* which a child can bring to bear on the problem. These include (1) *cultural predispositions* based on parental values for his sex and social class, (2) his mental ability, past experiences at similar problems, cognitive styles, social skills and physical development, and (3) a moderately well-formulated set of *motives* which serve to impel him toward work on problems or toward some competing activity. Finally, there are principles applying to the *teaching process* which show how modifications in the child's initial responses occur during his school experience. These will be discussed in turn.

Problem Situations Available to Child in First Years of School

Social

Learning to get along with teacher, including directing attention according to teacher's plan, sharing teacher's interest; learning to get along with peers; control of impulse; adapting self-concept from infantile omnipotence toward progressively more realistic levels; being able to respond in a group situation without anxiety.

Motor

Learning control of eye-hand coordinations; use of pencil and crayon; large muscle coordinations.

Cognitive

Learning reading, number work, some rudimentary science and social-studies problems, generating and expressing ideas in language, art, rhythm, assimilating, and appreciating literature, art, and music.

Much of the current curriculum at the kindergarten and nursery-school level revolves around the social problem areas, with less emphasis on motor problems and generally very little presentation of problem situations involving the use of cognition. Studies comparing children who have and have not attended kindergarten (or nursery school), when properly controlled for selection of sample, generally show some slight advantage later, in the social areas, for children who have had the preschool experience. Leadership is one such skill, representing some success at solving certain social problems.

No advantage has been shown for kindergarten attendance in the motor and cognitive areas. A study comparing reading achievement at the end of first grade in two groups of children, one of which had had a phonics program in kindergarten and the other the usual socially oriented program, found no differences in reading levels. The children who had had the social emphasis program were rated by the teacher as superior in social skills.

Most striking in the above list of usual problem situations is the comparative absence of cognitive problems involving learning other than reading and number work. We know that children of this age are bubbling with curiosity about scientific aspects of the world and are quite capable of thinking through problems appropriate to their level of development. Further, many children seem to enjoy solving problems, and when they have such opportunity, their sense of competence and set for future problem solving seem to be enhanced. Here is a clear challenge for research: What kinds of problem situations involving cognitive types of skills can be devised for young children to add meat to the present repertoire? To what extent can young children be sensitized to problem solving and to what extent will such abilities transfer either skill or self-esteem (or both) to new problems?

Resources With Which Children Enter School

For many years educational policy has acknowledged the facts of individual differences in children. What still needs considerable clarification is how to handle them so as to optimize the effects of instruction.

Sex

There is evidence that on the average, 6-year-old girls are more ready than boys at the same age to begin the process of learning to read. Small muscle movements are better matured in girls than boys, making neat printing and regular formation of numerals an easier task. Identification with the significant figure of the teacher, female in 98 percent of primary classrooms in this country, is probably *easier for young girls than for young boys. Thus, girls are in* general more well-behaved and responsive in the early years of school. These response patterns are usually strongly reinforced by the teacher, leading to over-learning on the part of the girl. But the price she pays for this early adjustment often becomes apparent in her later inflexibility in the school situation and life. The boy, on the other hand, cannot really permit himself this identification with the teacher and is left more opportunity for varied behavior and trial and error. Where the girl identifies with the teacher, the boy may identify with his peer group. Significantly, there is evidence that the girl's cognitive structure as well stabilizes much earlier than the boy's. Boys' scores on standard IQ and impulsiveness tests are still in a state of flux, while girls' scores have settled down to a predictable pattern at ages 6 and 7. Possibly boys are left freer and more flexible than girls in their later approach toward learning. Perhaps risk-taking, which is involved in much independent making of problem situations, becomes more possible for many boys as compared to most girls. Study is needed as to the degree of risk-taking in boys and girls at various points in their devel pment.

A recently completed study investigated the relation of "masculinity" in kindergarten boys to their success in learning to read in the first grade. Those boys who had already managed to turn toward masculinity learned to read more readily than those who had not, though there was no significant correlation in learning arithmetic, which is already at this age considered a "masculine" subject.

This points to another general principle: There are developmental problems or transitions in the child's life which must be resolved in order to free his mind for intellectual tasks. The school must do its best to facilitate solution of these transitions.

Cultural Predispositions

Cultural predispositions inculcated in the child by his parents or other agents of his particular subculture, facilitate the child's approach to problems when they are in line with goals of the school. When there is divergence between the values of teacher and child in respect to intellectual striving (as with a middle-class teacher and a lower-class child), the teacher feels, rightly, that there are powerful forces working against her.

The teacher must ultimately face the problem of how to initiate responsive behavior on the part of the child; for, unless the child responds, he cannot be corrected and there can be no learning. In middle-class environments the problem is frequently one of guarding against premature response that clouds the issue before enough information has been received by the child. But in lower-class and deprived classrooms, the child will not often respond readily. With *some readiness (perhaps trained in preschool) old tricks* such as the counter-intuitive example might help. But in general, where the problem begins long before school, only a detailed ethological account of the lower-class home will give us the necessary information to outline a design for modification. And even then, the process may take three or four generations.

A second critical problem is the need for an objective, sensitive *assessment* of the child's initial attitudes about the school situation before he enters school. The important dimensions to be investigated are fear, anger, what the child assumes will be expected of him in the way of competence, the sexual appropriateness of various school activities, how school is viewed as an avenue to an adult role, his self-confidence, and whether he conceives of school as appropriate to his age and his social and ethnic background. There seem to be two methods of measuring these dimensions: In the first, we place him in a relatively free play-situation and ask him to act out how he thinks a typical child, or his parents, might behave in such a situation. Related to this is Sears' technique of separating parent and child with a glass partition and allowing the child to "call" his parent on the telephone and assume various roles, such as that of a father saying he'll be late from work. The underlying assumption in all these techniques is that the child's verbalizations will reflect his perceptions. If this is so, we can derive a set of categories from our data and then devise more conventional tests of the various categories. But we must beware of confusing these fantasies which are the child's expectations of an unknown reality with fantasies which are a denial of an already known reality.

A more constrained technique, which gives greater objectivity, involves teaching the child a neutral mediational response such as a nonsense syllable or geometric form for each of the above dimensions, and then presenting him with various aspects of the school situation and asking him to label them with the learned mediational response. We might refine this technique by asking him to distinguish between two instances initially labeled in the same way and thus get a graded scale of his expectations of school activities. To some extent this is possible with doll play-situations as well.

Our hypothesis is that anxiety over the school situation, especially expectations that the teacher will be punitive or overly directive, is inhibiting to voluntaristic and initiative behavior. Therefore, any procedures which change the child's negative expectations into a belief that school is a free situation, permitting initiative, will improve the conditions for learning.

Mental Ability

Mental ability is highly correlated with competence in problem solving. Data from longitudinal studies suggest that curiosity, independence, and need achievement are related to increases in IQ (particularly in boys) in the early school years. Furthermore, the correlation between IQ and performance in school is higher in school tasks than in laboratory tasks, which are generally novel to the child.

This points up again the importance of getting the child to take his *first successful step in problem solving.* Children get trapped into one track early in their schooling, even in a classroom group designed to be heterogeneous in intelligence. The opinions of teacher and peers as to whether they are good or poor problem-solvers cast them into a role from which it is very difficult to escape. Effects of success (which cannot come unless one tries) are cumulative; the rich grow richer and the poor grow poorer over time.

A second point of importance is the need to *increase the proportion of non-verbal problem situations in the classroom.* Certain mathematical, spatial, and mechanical problems present excellent opportunities for practice of reasoning, but are not highly related to the predominantly verbal IQ. The researchable question here is the extent to which successful practice on such problems will (1) increase probabilities of success on later problems in the same area, and (2) show transfer to problems in other areas.

Cognitive Styles

Cognitive styles of impulsivity and reflection have been found to be general characteristics of children. It seems likely that impulsivity may serve the function of quick proliferation of ideas; reflection may play a critical, evaluative role. The child who responds impulsively may often be the first of the group to have the answer, and this appears to be reinforcing in itself to many children. However, the response is likely to be a poor one for lack of careful reflection; the child may be rebuked or ignored for his hasty contribution.

Here we need to know the effect on children who show differing styles of response over a period of classroom interchange and also the possible effects on group problem-solving of having available resources from children with different styles.

MOTIVATIONAL AND ATTITUDINAL FACTORS IN RECEPTIVITY TO LEARNING

Jerome Kagan

This paper addresses itself to the incentives within the child that predispose him to want to master academic skills. We shall not deal with the role of the stimulus conditions in which the learning occurs (proper manipulation of which facilitates attention and learning) or the existing cognitive structures possessed by the child. Rather, we are concerned only with those antecedent conditions and associated constructs that are responsible for the child's desire to master academic skills or for the inhibition of such mastery. It is assumed that these variables are the primary determinants of the degree of attention invested in the assimilation of new information.

It is suggested, first, that there are three broad classes of goals that motivate the child's learning of academic skills. Developmentally, the first goal is a *desire for the nurturance, praise, and recognition of significant others*. For the young child these others include the parents and teachers. For the adolescent and adult, recognition from peers and significant authority figures becomes relevant. These goals are external (or extrinsic) and operate with different strength during different developmental eras, being primary during the preschool and early school years and hopefully waning as adolescence approaches.

A second class of motives begins its growth at age 4–5 and involves the *child's desire to increase his perceived similarity to a model who is (1) seen as commanding desirable resources (such as power, competence, affection)* and (2) in possession of some attributes that are also shared by the child. Under these conditions the child will want to adopt behaviors and learn skills that he believes will make him more like the model. If the model is skilled at academic tasks and acts as if he valued such mastery, the child will be highly motivated to increase his academic talents. This motivational process is *intrinsic*, because the events that reinforce or maintain the mastery behavior are cognitive evaluations of a decreased discrepancy between the child's attributes and those of the model. We shall refer to this process as the "identification" motive, where identification shall be taken to refer only to the conditions outlined above.

Typically this construct has been neglected in discussions of the motivational conditions for mastery of intellective skills, and some elaboration of the significance of this process seems appropriate. Each culture develops a set of skills that its members value because the desirable adults of the community are proficient in these skills. The activity gains incentive value not only because social agents reward these activities directly, but also because adults who command power and status possess these skills.

For the young child, the parents are the prototypes of the desired and powerful adults. They exercise arbitrary power over him, they dispense tangible rewards, they give and take away affection. If the parents possess intellective skills and communicate to the child that they value them, the child will be strongly motivated to acquire these skills, for increasing mastery makes him feel more similar to his parents.

The identification sequence may help to explain several critical phenomena. For example, the marked differences in the motivation of lower- and middle-class children do not seem to be a simple result of differential reinforcement, for lower-class mothers frequently impose negative sanctions for poor school performance. The child's motivation is weak because the adult models he has chosen to emulate do not possess or display an interest in intellective skills. Thus the exhortation of a lower-class mother to her child, "You better do good in school," does not have the effect it has on children whose parents behave as if they valued this activity.

The sudden decrease in academic motivation in prepubertal girls also reflects this process. During grades 1-6 the girl's motivation is generally high and her school performance adequate. But the primary motivation appears to be extrinsic, for the girl is typically concerned with parental or teacher acceptance and works to retain their nurturance. As this motive wanes, her academic motivation wanes, because the models in her life—her mother and models from the mass media—usually do not manifest competence or concern with these skills.

This general process also touches the meaning of the phrase *the sex appropriateness of school tasks.* The child assigns the label masculine or feminine to tasks practiced in the culture, an assignment based in large measure on the ratio of males to females (or females to males) practicing the task. The larger this ratio, the more sex-typed the task. Since the child from age 10 on has crystallized an internal model representing an idealized male or female, he or she strives to maximize similarity to this ideal and avoids adoption of attributes that lead to increased discrepancy with it. Recent empirical work in our laboratory indicates that first-grade boys label school tasks as feminine, and only with age do they gradually change this perception and begin to view certain academic tasks as masculine (that is, sex-appropriate). It is interesting to note that the only school subject labeled as predominately masculine by first-grade boys and girls is arithmetic—the task on which girls show the greatest decrement in performance during ages 6–15.

A third set of events that is clarified by the concept of identification is the dramatic effect of the master teacher on commitment to intellectual involvement. Most of us acknowledge the ability of a particular teacher or professor to catalyze a major increase in the desire to master intellective skills. This is most likely to occur when the teacher is perceived as accepting of the learner, competent in his area, and in command of tangible and intangible resources that the child values. This experience persuades the child or adolescent that mastery of the skill taught by the desirable teacher is "valuable," and the learner now has a more powerful reason to work at mastery. The subgoal reinforcements that maintain this behavior are the perception of decreased discrepancy between the child's level of skill and that of the model. The autobiographies of the intellectuals of our society typically contain references to contact with such models. The dramatic effect of a Robert Davis or a David Page is mediated, in part, by the fact that they are seen as desirable models by the child—non-punitive, accepting, extremely competent, and in command of desirable resources (that is, they travel by jet from State to State, and are presented as status figures to the class). In sum, the desire to make oneself similar to a desirable model who incidentally displays competence or involvement in intellectual tasks supplies a primary intrinsic motivation for receptivity to learning.

A third class of intrinsic motives involves the desire *for competence* and *self-worth*. At this point in the immature development of psychological theory, it will have to be taken as a primitive assumption that all individuals strive to attain attributes and skills that they and others will interpret as signs of competence. Some signs of competence are culturally derived and dependent in part on membership in particular reference groups. For the male, physical strength, sexual adequacy dominance in interpersonal relations, skill in exploitation of the physical environment, and vocational competence are observable signs generally thought to indicate competence.

Intellectual competence is differently valued by boys and girls in different social classes. Until recently, education has been one of the chief routes to upward mobility in this country; to aspiring parents the school grades of children have represented important sub-goals in the process. If future occupational competence involves professional or graduate training, intellectual competence may be more important for males than for females. In some other social class groups the intellectual skills exemplified by accurate spelling and computation are probably valued more for females, who may go into office work.

Preadolescent girls at about the 5th-grade level begin to show decreased intellectual motivation, at least overtly. This probably results from a conscious effort to play a more submissive, less initiative and problem-solving role in relation to the boys in their environment. Such a flight into femininity seems to remove the girl from problem-solving situations, and ends indeed in reducing opportunities for problem-solving. The impact of this flight might be somewhat mitigated if the curriculum included problems viewed by the girls as "feminine."

Boys, too, sometimes try to flee the cognitive arena. For boys of inferior mental ability, the anxiety engendered by the unequal struggle to achieve intellectual competence leads to defensive maneuvers of various sorts, one of which is distortion of their perceptions of themselves and their performances. Since in every class group there will be children below the mean of the group in mental ability, this is a problem to be faced realistically by curriculum planners. The solution may lie again in the variety and scope of problem situations made available to the children.

This position regarding the use of intellective power to attain (or prove) competence is slightly different from the simple view that "the human being likes to practice the skills he possesses"; for it is apparent that a child or adult likes to practice skills about which he has some uncertainty—skills around which he has a penumbra of doubt regarding complete competence. If a person is *completely* confident of his ability to perform an intellectual task with elegance, it loses some of its attraction. It is the mild uncertainty that spurs motivation to mastery.

In sum, we have described one extrinsic and two intrinsic sets of motives that make the child receptive to school learning. We believe that many differences in school performance among children can be accounted for in terms of the child's motives and his school experience in the first 3-4 years of school. One should probably assign different statuses to those children who enter school with both extrinsic and intrinsic motives, allied with intellectual success and to those in contrast for whom there is a weak link between goals that incite and school competence. That is, the child who perceives parental nurturance as contingent upon school mastery and who wants to maintain this resource will enter school ready to learn. If in addition this child has adopted as an identification model a parent or parent surrogate who exemplifies mastery, the motivation to mastering reading and mathematics will be that much stronger. For this child, arrangement of curriculum, proper sequence of subject matter, and manipulation of stimulus materials should have importent facilitating effects on the breadth and ease of acquisition. *But it is not trivial to note that these children enter the school with a desire to learn.*

Let us contrast this child with one whose parents have not made nurturance contingent upon intellective mastery (thus there is no intrinsic motive to learn) or who has experienced so much punitiveness and pain during his first five years that he has no desire to strive for parental approval. If in addition, as is often the case, this child has not been exposed to models who practice and value academic tasks, he enters school not only with a minimal desire to attend to information but also with a set of competing motives that are probably inconsistent with the response of attending to communications from teachers, workbooks, or machines. For this child—and 40 percent of our population is made up of such children—the first step is to make him more receptive to learning by increasing his motivation to master. This can best be done if the child is put in close contact with adults with whom he can identify. In effect, the teacher must salvage this child before any particular curriculum can have an effect on him.

Suggested Investigations

These ideas contain implicit suggestions for several critical investigations. Let us make some of them explicit.

Project 1

To study the effect of *similarity* between teacher and child on the child's receptivity to learning. In this investigation one would vary sex of teacher and the degree to which the child perceived basic similarities between self and teacher in interests, class, and ethnic and racial membership, and then study differential learning in individual or classroom situations.

Project 2

To study the effect of the sex-role appropriateness of the material to be presented on ease of acquisition. One would create maximal and minimal congruence between the sex of child and content of material to be mastered and contrast the ease of learning.

Project 3

To study the differential effectiveness of curriculum change on children high and low on initial motivation to master. In this study, one would assign children to groups high or low on initial receptivity based on indexes of their perception of school and intellectual mastory. One-half of each group would be assigned to one of two curriculum treatments with the presumption that the effect of curriculum would be marked for high receptives but negligible for the lows. These are but samples of studies by which one might attempt to assess the importance of initial receptivity.

INHIBITORY FACTORS IN ATTENTION AND MASTERY

Jerome Kagan

The phrase "inhibitory factors" refers to motives that direct the child to inhibit attention and involvement in learning and problem-solving. As used here, it does not refer to the absence of skills necessary to acquire a new bond or solve a problem. There are at least six inhibitory motives, each of which will be discussed briefly.

Expectation of Failure

This refers to a child's belief that he will not be able to perform a task adequately. By age six the child has become sensitive about exposing himself to others, and has crystallized a sufficiently clear internal definition of self so that he becomes anxious when he *invests himself in a task and fails.* This implies that the 6-year-old already has a strong need to regard himself as competent. Assuming that the child will refuse to risk success by attempting to solve the problem in order to avoid recognition of inadequacy, then it follows that, if the child anticipates an inability to perform on a problem, he will not begin to solve it. He will avoid recognizing it as a problem, or he will acknowledge it but refuse to offer hypotheses. Unfortunately, this habit becomes stronger with practice, and by late adolescence one finds the common syndrome of the capable student who is failing because he is not working. The internal logic is clear, and the dialogue in the student's unconscious runs something like this: "If I do not work and fail, I have supplied myself with the important alibi that I could have done the task had I studied." To study and fail is intolerable; to avoid study and fail is acceptable. The false premise is the fixed belief that, despite work, failure is inevitable.

Since this sequence begins so early and grows in strength so rapidly, it is critical that the teacher and the school prevent this response from occurring. The teacher's best strategy is to structure tasks so that failure is not likely to occur and to structure the social situation in the classroom so that the humiliation accompanying failure is minimal. In effect, the risk of failure must be kept as low as possible.

Sexual Congruence

A second cause of inhibition is a labeling of the substantive materials to be mastered as inappropriate to one's sex. Briefly, the child of six has acquired an internal standard that dictates his striving to maximize similarity to his conception of the ideal boy or girl. Correlatively he must avoid involvement with the materials that are labeled as predominantly characteristic of the opposite sex. Since mathematics, intellectual competition, mechanical objects, aggressive objects (to name just a few) are viewed as masculine by children and adults in our culture, the girl inhibits involvement in such tasks. One can, of course, list feminine contents that lead to inhibition among boys.

Lack of Congruence Between Mastery and a Change in Role

In addition to a classification of domains of knowledge as appropriate to male or female sex roles, the adolescent and adult may also have learned to expect that, following mastery, people will begin to react to him (i.e., place him in a role) in a way that he may not want. The two most frequent expectations people develop toward a person who displays mastery are (1) independence and responsibility and (2) a display of power. It is not difficult to see how the adolescent may have learned this sequence, for adults and peers do change their behavior toward those who manifest competence. Frequently, masterful people are placed in positions of power and of responsibility. If the person is afraid of such roles or has labeled them negatively, he will inhibit attempts at mastery.

Two examples should suffice to illustrate this. The author knows of one boy who, between the ages of six and ten, was ostracized by a group of peers who formed the power elite in his school. As a result, he labeled both these boys and the more general category of "power people" as negative and made a secret vow never to assume such a role. He attended a college where academic talent led quickly to election to power roles on the campus. After two years of good grades—and election to one or two power positions—he began to inhibit academic effort, although unaware of the reasons why. Some individuals are afraid that mastery leads other people to expect responsible and independent actions from them. If the individual has strong dependence needs and feels unable to deal with the major stresses of his environment (despite the fact that he may be academically talented), he will inhibit mastery in order to avoid being placed in the feared role. The author knows several college girls who obtained excellent grades during the first three years on campus but began to fail in their senior year. Conversations with them revealed quite clearly that they feared graduation because they viewed this event as a change in their dependent status. Their fear of marriage and the choice of a career was strong, and they wished to retain their dependent relationship with their parents. By inhibiting involvement in academic mastery they postponed graduation and the change in role.

Conflict With Affiliative Needs

A very common source of inhibition of academic mastery stems from the common peer-group attitude toward the academically talented student. Except for children who grow up with a homogeneous peer group that values intellectual mastery, most children and adolescents who do well in schoolwork are subject to rejection by their peers. The peer group values mediocrity and resents the display of excessive talent by one of its members. For the child who has strong needs for peer acceptance this conflict can lead to an inhibition of mastery in order to retain the acceptance of his peers.

Inhibition of Mastery and Gratification of Hostile Motivation

Another common source of inhibition of mastery lies in the student's belief that academic failure will cause anxiety to special social agents, usually his parents. Thus if the child has strong hostile feelings toward his parents and has been unable to gratify them directly, he may choose failure in the school situation as the route for gratification. This is most likely to occur for those children whose parents display an active concern with the child's mastery but who excessively frustrate the child through over-restriction, over-punitiveness, or rejection.

Self-Depreciation and Inhibition of Mastery

The last inhibitory factor to be discussed is not a common one and indeed requires an unusual set of personality developments. Briefly, the point to be made here is that, if the child has developed strong feelings of guilt and unworthiness, he will gradually come to believe that he is not entitled to any positive or gratifying experiences. If his social environment is one that values academic success and rewards it with affection or tangible goods, academic success becomes a positive experience and one that leads the social environment to label the child as a valued and worthwhile person. It is obvious, therefore, that the child who has become unconsciously convinced of his worthlessness will behave in a way to maintain this image rather tion to cause dissonance. Although there is no systematic research on this issue, the clinical literature indicates that there are some individuals who have developed excessive guilt over hostile and sexual thoughts or behavior. This chronic guilt leads the child to inhibit any set of behaviors that would cause the social environment to respond toward him positively. At times, this has been explained by labeling the child as one who sought to punish himself. It is suggested here, however, that it is more fruitful to view this kind of behavior as a result of the child's need to avoid dissonance between the sets of labels he has applied to himself and the labels the social environment places upon him.

A critical construct involved in many of the processes outlined above is the child's internal standard regarding the roles he wishes to assume. Once a particular standard becomes entrenched, the child tends to structure his environment and to initiate future behavior in a way to avoid any dissonance or internal or external contradiction between the role labels he has applied to himself and the ones that might result from academic mastery. Although the evidence is meager, it is suggested that these standards are laid down between the ages of five and ten years; if this is true it is apparent that the first four or five years of school are critical times in which to watch for sudden shifts in the child's motivation for academic mastery. Longitudinal study of a large group of children between the ages of five and ten in an experimental school or in the traditional school settings would be of immense value in furnishing basic empirical information on the antecedent causes for these kinds of personality developments and the possible therapeutic techniques that might be used by teacher, peers, or parents to attenuate them.

PROCESS PLEASURE

Solo. [illegible]

While it is obvious that various classes of intrinsic or extrinsic motivations are essential for both the initiation and maintenance of action and the incubation of learning, there is one additional factor that must be taken into consideration in the construction of curricular materials. This is the factor of the intrinsic interest of any activities which the child performs. If a task is emotionally boring, the amount of attention or approval that its completion may bring forth from an admired adult is insufficient to overcome negative aspects of the task itself. For an 8-year-old boy, spool packing can never compete with the construction of a helicopter from an erector set.

There seem to be two aspects to this intrinsic quality of materials and tasks. One lies in the initial stimulus quality of the materials that are used, and the other in the process of working with them. Certain stimulus qualities elicit initiative in taking up the task, and certain qualities of the process of working on the task can bring about some degree of pleasure. The major importance lies in this latter quality, namely the pleasure obtained from the process of working on the task.

It may be valuable to consider which qualities of a task process contribute to the pleasure derived from it.

Manipulability

In the earlier years especially, the amount of manipulation that a task permits seems to be positively related to its pleasure. Construction materials, engines, compasses, kaleidoscopes, or indeed any objects that can be manipulated to secure a change in its status, are of far greater attractiveness and give more pleasure in the use than inactive objects such as pictures.

Indeterminacy of Control

There appears to be more process pleasure when an instrument is not entirely within the control of the child. When the task is a little more difficult than the child's skills can fully encompass, it has a built-in indeterminacy because the child's efforts are not completely successful in the beginning. Likewise, if there are multiple manipulations to be made, especially ones which must be coordinated, there is bound to be some slippage. If the child must overcome difficulties or learn the *rules* for combination of multiple units, he seems to enjoy the task more.

Multiplicity of Consequences

The more complex the outcome of the child's manipulations, the greater his pleasure in the process. A simple one-to-one relationship between the movement of a lever by the child and the appearance of a light on an instrument is substantially less satisfying than the movement of a lever that sets in motion a series of changes in an instrument (like an electric train) that then have their own consequences. The more the consequences and the more they require in the way of continued response by the child, the more pleasure there is in the process of working with the instrument.

Novelty

This variable refers to three classes of things: the stimuli that are presented to the child, the responses that the task requires of him, and the outcome of his manipulations.

Similarity to Realistic Adult Tasks

The more nearly a task resembles the kinds that are characteristically undertaken by adults or other identificants of the child, the greater the pleasure in the process of working with the instrument or the task. There is an important qualification of this principle, however. With tasks or instruments that are entirely inappropriate to their own age or developmental status, children have a tendency to move into fantasy solutions and to perform at a fantasy level. For example, an old automobile placed in a nursery school playground will elicit a great deal of manipulative activity that is adult in form but not truly adult in intention on the child's part. Boys will sit in the car and make sounds like the engine, make shifting motions and steering motions, constantly performing in a fantasy way like an adult. On the other hand, a child with a small car that is propelled by pedals will ride it around avoiding obstacles, steering effectively, braking, and may even use his hand for signaling just as an adult would. This kind of play is much more realistically oriented than is play with the real adult automobile. Similarly, with respect to nurturant behavior, a child taking care of a puppy or a guinea pig will actually feed it and will treat it as a creature to be taken care of. This is quite different from caring for a crying baby doll that is dressed up in all sorts of fancy clothes. It is our impression that, for learning skills and problem-solving, fantasy activities are less useful than realistic activities. Hence tasks should be graded appropriately according to the age of the child, even though greater interest might occur briefly in the fantasy activities resulting from truly adult tasks—tasks on which, nevertheless, the child cannot possibly be expected to behave with the expectations of adult outcomes.

PRODUCT PLEASURE

Robert Sears

The process of working on a task is not the only aspect that can give pleasure. There is also the product to be considered. Many of the tasks that are used for learning experiences end up with some outcome of a strictly physical nature. There are written stories, geometrical constructions, arithmetical computations, paintings, sculpture, and the whole gamut of artifacts created in connection with units in the social studies. Because these products represent the end point of the child's performance, inevitably they have high value for him. The extent of this value determines, in at least some small way, the reinforcement value they can have for the learning experience through which the child has just gone. Anything that can be contributed by curricular construction or the development of "hardware" which increases the attractiveness of end-products will automatically maximize their reinforcement value.

Children enjoy seeing a good clean, neat product. They like to see bright colors and sharp edges. They enjoy a workmanlike piece of building and an accurate fitting of joints or lines. An angle which does not waver is more attractive than one that does. Printing that is precise is better than sloping, straggling handwriting. The basic quality involved in this cleanliness and neatness is essentially an adult quality, and the nearer a product can approximate what an adult would turn out in cleanliness and neatness, the more it satisfies the child.

In discussing process pleasure, we pointed to the dangers of producing fantasy behavior that approximated the adult role. The same restrictions doubtless hold with respect to product, although if the child is able to manipulate certain instruments, such as a typewriter, to produce adult-like products, the danger of fantasy as an alternative to reality is probably negligible. A teacher we know used a typewriter for recording children's stories. Each child sat down and planned his little 8- or 10-line story, after which the teacher typed it in very large print from the child's dictation. The youngster could then have in his hand his own story in his own words, and could take it home and show it to his parents if he wished. His story was just as good in physical format as anything the greatest novelist in the world could put on paper.

Quite aside from the desirability of neat adult-like products as objects in their own right, there are simple mechanical devices that serve to ease the physical or mechanical processes that must be gone through in solving problems. For children in the first two or three grades, writing and printing are slow and often painful procedures for getting ideas on paper. While these are skills that must be learned, it is doubtful if they should be practiced in connection with difficult problem-solving that has something else altogether as its aim. Typewriting, for example, is an easier operation and results in a more attractive product than the laborious process of writing. Perhaps this accounts for O.K. Moore's surprising success in teaching reading by the use of typewriters.

The invention of such mechanisms requires only some imagination. Besides typewriters, mimeograph machines or even small individual printing sets could serve as substitutes for writing and printing by hand. In arithmetical work, simple devices that simulate slide rules or other instruments can be devised or are already available; the abacus is a notable example. Desk calculators are available in very simple and inexpensive form. For social studies units, there is no reason why standard equipment could not be designed and manufactured permitting solid construction igloos, Indian huts, woven materials, and so on.

Research Implications

In this final section several significant research problems will be described briefly. The extensive discussion of motivational and attitudinal factors contained in the previous pages suggests the relevance of these investigations.

1. A Study of the Effect of Perceived Similarity Between Child and "Teacher" on Speed and Comprehensiveness of Learning New Knowledge

This report has stressed the importance of the teacher as an ideal model in facilitating the child's involvement in intellectual problems. It was suggested that two important factors were (a) a perception of similarity to the model and (b) a perception that the model valued the intellectual skill to be mastered.

In this study four independent groups of children could be subjected to four different treatments. The dependent variable would involve the ease of learning an academic skill in which the child had no prior training. For group I the "teacher" would be perceived as similar to the child in sex and interest and value patterns and as behaving in a way indicating that he (she) valued the academic skill. For group II the perception of similarity would be high, but the model would indicate no mastery or concern with the skill. For group III, the model would be minimally similar to the child, but manifest value of the skill. For group IV the model would be minimally similar and indicate no concern with the task. It would be expected that group I would show the fastest acquisition of the new skill and group IV the slowest, with some question of the differential performance of groups II and III.

2. Diagnostic Instruments Should be Developed for Assessing the Childs' Initial Responses to Problem Situations

These assessments could well include some of the motivational patterns: desire for acceptance, desire for identification, desire for competence, process and product pleasure. Responses of recognition and classification of problem situations, initiative in attack, and persistence should be elicited from a variety of tasks tested for level of difficulty, novelty, and potential for transfer to the type of problem situations encountered in school. In addition, young children's expectations with regard to the classroom need to be investigated and their interests in the various curricular areas explored.

3. An Analysis in the Classroom of the Effects of One Teacher Versus Multiple Teachers on Children's Performance Would Be of Great Interest

As we know, the typical arrangement in the early elementary grades is to have one teacher for all subjects. There are arguments for utilizing more than one teacher at these ages because of the differences in competence that different teachers possess with different subject matters, but an argument can also be made in terms of the different motivational and reinforcing effects that different teachers may have on different children. Some adults seem to be particularly effective with particular children. If in the typical classroom the child is assigned a teacher who is effective for him, he should do well; if the teacher is less effective for him, his performance should be less adequate. One might hypothesize that the variability of a child's performance in school would be increased if he were to encounter a number of different teachers. We might predict, therefore, that within-child variance in academic performance would be greater in multiple-teacher classrooms than in one-teacher classrooms. If the positive effects of having a particularly desirable teacher were to generalize to other areas, one might predict that the initial increase in variance would then decrease, but that the mean level of performance of all children would be above that occurring if they were to be taught by one teacher.

4. There is a Vital Need To Test Systematically the Possible Effects of Special Kinds of Instruction on Children's General Approaches to Cognitive Problems

More specifically, it may be hypothesized that teachers, using special instructional techniques, can modify (improve) children's behavior related to each of the major response systems discussed—recognition and classification, initiating response and persistence.

To test this hypothesis, special instructional techniques must be collected or designed and described in detail. In addition, tests of each of the response systems (preferably *behavioral* tests) must be carefully devised and adequately standardized for different age groups.

Large numbers of children must be assigned randomly to experimental and control groups. The specially designed tests would be administered to the experimental group *before* and *after* instruction designed to strengthen recognition, initiating, and persistence responses. The control group would also be tested twice, the two test administrations being separated by the same interval of time, but during this interval the subjects would have received only the usual kind of classroom instruction. The hypothesis would be confirmed if the experimental subjects showed greater improvement than the control subjects between the first and second tests.

CHAPTER II

REPORT OF THE WORK GROUP ON COGNITIVE SKILLS

COGNITIVE SKILLS

Mary Henle

This section will be concerned with certain cognitive skills that facilitate learning and that themselves might be trainable. It is, of course, impossible to say in advance of specific empirical research which skills are teachable. At any rate, it is often of no practical importance whether particular skills can be taught or whether preexisting abilities of the learner are brought out, activated, directed, or organized in the course of teaching. Since the relevant research is so largely lacking, the statements that follow are to be regarded as hypotheses that the skills in question *can* be taught or improved or activated through training.

There is no implication in the paragraphs that follow that the basic processes involved in learning are themselves products of training. Curiosity, for example, may be aroused, directed, narrowed, or stifled, but cannot itself be taught. Likewise in the case of other cognitive processes, we shall be concerned with the use to which they are put, the conditions under which they are activated, etc. We will be concerned with skill in the use of the mind, not the learning of cognitive processes as such.

It is, of course, impossible to make an inventory of all the cognitive skills that enter into and facilitate the learning process. Emphasis here will be on those that are considered to make the learner independent of the teacher. This emphasis derives from the conviction that education must be for self-education. With the accelerating rate of research and discovery, the correspondingly rapid obsolescence of knowledge, and the relatively small amount of time available for formal education, we consider that the task of the schools is increasingly one of teaching students to continue their education. The learner must be given increasing responsibility for his education, made a partner in the enterprise of teaching.

For purposes of the present part of the discussion, skills will be considered without regard to the ego level at which they can be brought to bear on the learning process. It must be pointed out, however, that it cannot be assumed in advance that the skills of the child are delimited in the same ways as those of the reasonably literate adult. The adult skills might—as one possibility—be differentiations from the more primitive ones of the child.

Instruction optimally involves a range of situations demanding of the child acquisition of knowledge, understanding, problem-solving, and creating.[1] The attempt will be made, in the following discussion, to enumerate a number of possibly trainable skills that facilitate each of these learning processes. Of course, the distinction between the various kinds of learning is by no means as clear as these categories suggest. The amount of sheer acquisition of material without understanding is being reduced as new curriculums are being developed. In many instances acquisition merges into understanding. It is not possible, for example, to deduce the dates of the great voyages of discovery, but it is possible to understand that they presuppose certain conditions that set limits on the possible dates: a certain development of the chronometer, certain geographical assumptions, particular political and economic conditions, etc. Again, the act of understanding may itself be creative, involving the discovery, the upsetting of old assumptions, the individual achievement that we ordinarily associate with creation. Still, as rough categories, these kinds of learning processes define our field and will be used to structure the following analysis.

Acquisition

1. Attention is a directive process that exerts a selective influence on perception and other cognitive processes, the direction deriving from the intention of the learner and/or from the nature and specific demands of the material to be learned. Seen in this light, the problem of training attention would be eliminated if the material could be made sufficiently compelling and varied or sufficiently relevant to the existing interests of the learner. But since, in practice, this ideal is only imperfectly attainable, the question remains: Is the directing of attention a trainable skill, so that the child can learn to focus and prolong his attention? Or is the problem one of setting up the proper conditions for the arousal of attention? In connection with the first alternative, techniques of gradually prolonging periods of concentration, of increasing the active participation of the learner, etc., must be tried. In connection with the second, the cooperation of the learner must be elicited in relating material to his interests; an additional task is that of exploring the material in order to bring out its properties most clearly so that the learner will be held by them. It may be noted that, far from training attention, many practices in school fragment attention.

---

[1] The question of the optimal proportion of each of these kinds of learning will be reserved for another part of this report.

2. A help in the capturing of attention as well as other aspects of the process of acquisition is the training of a set on the part of the learner to seek relations, connections between the material to be learned and known material. This has the dual effect of eliciting the interest of the learner and removing the arbitrariness of the learning by developing its context. What is the relevance of this new material to what I already know? What is its relevance beyond the classroom? In this connection the teacher has an obligation to justify the subject matter (e.g., why does one study geometry?).

3. Among the relations to be given particular weight are those of similarity and difference. If new material can be shown to have a particular similarity or to be different in a specific aspect from known material, it is already partially learned and its relevant context has been partially explored.

4. Likewise a set for structuring and coding of material to be learned can be encouraged as an aid to acquisition. It is well known that the number of items that can be kept in mind, handled, and remembered is enormously increased when the items are grouped. When the material does not possess an internal structure, one must be imposed by the learner. Here, as little arbitrariness as possible should be introduced. It is, for example, possible to order the English kings by name: the Henrys, the Edwards, etc., but more sensible groupings are, of course, preferable.

An impressive demonstration of the usefulness of grouping could be made simply by asking children to learn a list of unrelated words, testing for recall, and then learning and testing a similar list held together in the context of a story. The increased power of the second method would be obvious.

Along with grouping, the importance of flexibility of grouping must be emphasized. Particular groupings may be adequate at a certain level of knowledge, but must be changed to encompass a wider range of material or in the interests of a new task.

Nothing has been said about training skills that might increase memory for learned material. In the absence of relevant evidence, it is here assumed that any measure that increases the effectiveness of acquisition (structuring, directing attention, etc.) enhances retention. Although under experimental conditions it is sometimes possible to increase retention independently of the level of initial learning, such results cannot automatically be applied to the classroom situation with its long-term, many-track learning of material often more meaningful in itself than the laboratory materials and often organically related to previously and simultaneously learned material.

For the same reason the question will not be raised of whether there are techniques of transfer that can be learned. It seems plausible that the question is again one of effective learning. Indeed, transferability of knowledge is often used as a criterion of understanding; and any suggestions that might be offered for increasing transfer would amount to suggestions for effective learning by understanding.

Although the question of training skills that might improve retention has been bypassed, the possibility of training for effective note-taking might be explored. This would involve a number of skills enumerated above, as well as others to be discussed below: organizing, bringing out relations, summarizing, simplifying, restating, etc. The adequacy of notes might be tested in a manner similar to Roger Brown's suggestions for testing understanding: by exchange of notes among students. It remains, of course, an empirical question at what age levels and in what connections note-taking is useful.

Understanding

In the discussion of acquisition, emphasis has been on procedures that would make it as much a matter of understanding as possible. The present discussion is thus a continuation of the one just above, and the devices suggested above for improving acquisition are relevant for more meaningful learning. Other possibly trainable skills to improve understanding will also be suggested.

It must be stressed at the outset that understanding is no less active a process than acquisition or the other phases of the learning process to be discussed. Although we "see a point," it is not simply a matter of opening our eyes and seeing it. To understand anything is to grasp its structure, but that structure may be hidden because of the difficulty of the subject or the limitations of the learner. It is the responsibility of the curriculum builder and the teacher to understand the subject as well as possible, so as to bring out the structure of the material as well as possible; but while this may facilitate understanding, it will not insure it.

Before we come to cognitive skills that might help understanding by the child, it must be emphasized that criteria are lacking for "good" vs. arbitrary structure, especially in the humanities and social sciences as compared to mathematics and the physical sciences. The lack is a serious one both for the teacher faced with the problem of how to make a given material understandable and for the learner who wishes to know how far he has understood it.

1. A first skill which might contribute to understanding, and the neglect of which is perhaps attributable to its obviousness, is that of recognizing when one has understood. It perhaps is of no practical importance whether this is a teachable skill or a capacity that can be activated and put to work. In either case methods of testing understanding must be developed so that the child can distinguish

between when he has understood and when he has failed to understand. One such test, suggested by Roger Brown, is to have one child describe a lesson to another who has missed it. If the second child is then able to solve problems or formulate a principle or pass other sensible tests on the lesson, the first child may be said to have understood it. Another procedure for testing understanding is to have the child rephrase what he has learned in his own words. This not only tests his grasp of the material, but may enable him to eliminate irrelevant meanings in the original formulation, helping to get down to the essentials, and it may also increase involvement with and commitment to the problem. Another device for testing understanding has already been mentioned—the transferability of what has been learned; this may at first be a help primarily to the teacher, but it may perhaps come also to be used by the learner himself.

A special problem in connection with knowing when one has understood is that of knowing how far to push understanding in a given case. Any material permits various levels of understanding at a given level of the development of knowledge (cf. Bruner's remark that any material can be taught honestly to a child of any age) and the limits of understanding are extended as knowledge advances. Ideally any child should understand materials as deeply and as fully as his cognitive development permits. In practice, however, the limitation of time and of human energy demands compromises; and it is desirable that the choice be a conscious one. It is desirable, furthermore—both as a test of understanding thus far and as a door to the future—to know how one would proceed in a return to the subject. A child should be able to recognize, for example, that here is an area where there is a lot more to be understood, even though his present interests take him further in a different direction (for example, shall I be content with a "strip map" knowledge of the Cambridge area so that I can devote more time to thinking about the instruction process?).

But however far understanding is pushed in a given case, it is important to distinguish it from that level of vague familiarity with a subject that leads a child to say: "I know what I mean but I can't put it into words." As this example suggests, the need for clarification and for recognizing understanding is just as great in connection with one's own ideas as in connection with material presented in the school setting.[2]

---

[2] A problem related to that of knowing whether one understands is that of knowing how much one knows, knowing the approximate limits of one's competence in given areas. It is important to recognize the difference between a wild guess, an informed guess, an hypothesis, an intuition, and a statement of fact. Whether teaching can develop this ability without putting a damper on confidence and cognitive exploration—and if so what kind of teaching—is a problem worthy of attention.

2. Since understanding is a matter of grasping the structure of the material, any device that serves to make clear or bring out this structure is helpful. The use of ikonic representation—e.g., the drawing of diagrams—is discussed elsewhere in this report.

3. The ability to simplify is probably a skill that can be trained. The point of simplification is not simplification as such but to strip material down to its essentials with a view to bringing out its structure. Thus training to simplify needs to develop the distinction between appropriate and inappropriate simplifications—those that do justice to the structure of the material as contrasted with those that violate it.

Among inappropriate simplifications, special mention may be made of the tendency to regard everything as either good or bad, black or white. Nor is it sufficient, in many cases, to introduce grays into the series: the tendency to view differences as one-dimensional is itself an inappropriate simplification. Cognitive analysis of the thinking of adults and children might well set itself the task of identifying other common but inadequate simplifications with a view to defining the requirements of appropriate simplification.

4. The set to seek regularities, to find principles governing the order of given sets of data, to seek cause and effect relations, to look for consistencies across data realms can very likely be induced by appropriate training. Such a set can lead to extension and increased coherence of one's knowledge and to the kind of simplifications that illuminate the structure of the material to be learned.

5. The ability to make a summary statement from a batch of details is as much a matter of testing one's understanding as improving it, and can very likely be developed by appropriate training.

6. The search for "symmetries" (Bruner) is a means of increasing one's understanding that has wide application. Thus if country A attacks country B, did country B do anything to provoke it? If the nobility is hostile to the king in a particular period of a nation's history, what did the king do to arouse it?

Problem-Solving

Problem-solving is the kind of learning that was most discussed at the conference. It is the kind of meaningful learning about which psychologists know most and which is most easily investigated by experimental methods. The present discussion will start with Richard Crutchfield's investigation of training for problem-solving. The skills that Crutchfield attempted to develop will not be considered in detail here since they will be discussed in a later section of this report. But they cannot be omitted here because they are essential to the process of problem-solving and, Crutchfield's evidence suggests, are improvable in the course of training.

1. The confusion between a *problem area* and a specific, solvable *problem* is not uncommon even among advanced students. It is the difference between knowing that I want to know *something* about a particular area and knowing the specific question I want to answer. The distinction is not a difficult one once attention is called to it, and Crutchfield's data suggest that specific teaching can help the student to make it.

In this connection the question of what is a problem is a pertinent one. Not all questions are problems that the learner can or need solve. For example, the question: what is the population of India? is one that the student can answer more reliably by consulting an almanac than by debating the issue or deducing it from premises. A remark of Boring is relevant to this matter: the student must decide when he is going to consult the library and when observe nature. Or, when is a problem to be dealt with by thinking about it? In our enthusiasm for inducing a problem-solving attitude, it is important not to forget that the purpose of education is not only to train problem-solvers, but to acquaint the learner with his cultural heritage.

2. Asking questions is a very important aid to problem-solving and one that was emphasized in Crutchfield's training experiment. In this connection, it may be added that the aim is to lead the child to ask the *right* questions not just any questions—although asking even "wrong" questions is probably better than asking none from the point of view of engaging the child's interest in the task. It remains an important question for research whether children can also be helped to ask the right questions. This involves, perhaps, sensitization to the requirements and limitations of problems, a sense of disharmonies and discrepancies and incompleteness. The discussion of intuition below may be relevant. In addition, the right question is often one of locating the specific difficulty, and relevant sets can be induced.

3. Crutchfield's training included encouraging the problem-solver to take a careful look at the facts, at the given details, to restudy what is there, to look for discrepancies.

4. Generating many ideas is a characteristic of good problem-solving and can be encouraged, as Crutchfield's data suggest. This is not only a matter of fostering an attitude friendly to getting many ideas; specific help can also be given in ways of inviting ideas.

Crutchfield suggests, for example, taking a walk when one is blocked on a problem, in the hope that a varied perceptual environment will suggest something that may lead to solution. It is helpful to look everywhere for clues, hints, ideas. Another helpful device is the use of metaphor or analogy. When one has run out of ideas on a particular subject (Crutchfield used the example of child-rearing), it is often helpful to find a metaphor (say the cultivation of plants), to think about this topic, and finally to apply the relevant ideas to the original topic. Another effective use of analogy is to ask whether the given problem resembles a known one.

The practice of focusing on different aspects of objects may also be useful in problem-solving. If an object needed for problem-solving is lacking, another object may be found to possess the needed attributes if one examines it in a new light. Although a weight is lacking in Maier's pendulum problem, pliers may be seen to be a workable substitute if viewed with fresh eyes. The relevant set is one of overcoming functional fixedness (Dunckner); a few dramatic examples may serve as a prophylaxis. Further thinking and research on ways of encouraging the generation of many ideas are needed.

5. Although a critical attitude is necessary at certain stages of the process of problem-solving, Crutchfield suggests that students should be encouraged not to be too critical too soon. A critical attitude may discourage the appearance of ideas, and an idea that sounds silly at first may, on reformulation, prove to be just what is needed to solve the problem.

6. In the course of successful and unsuccessful problem-solving, specific strategies for the solution of problems can be brought to the attention of children. The following are suggested not as an exhaustive list, but as samples of strategies that can probably be taught.

Proper planning is often a prerequisite to successful problem-solving. Often a problem as given cannot be solved by a child, but it yields to solution if it is divided into sub-problems and a more step-by-step approach is adopted. It is important, of course, that such subdivision be done without losing sight of the goal and that sub-problems be both soluble and steps to the goal.

Another teachable strategy would seem to be the reformulation of questions. Sometimes questions as asked cannot be answered, may indeed suggest a misleading answer, and require reformulation before an answer can be found. Duncker described the successive reformulation of questions until solution occurred. A common device of detective fiction is, at first, to formulate questions in a misleading way; the mystery would remain insoluble if the question continued in its initial statement. Indeed the selective use of detective fiction might provide interesting demonstrations of misleading and helpful formulation of problems. A question properly put, as James Stephens once remarked, brings along its answer on its back as a snail carries its house.

Another useful strategy of problem-solving is to define the boundaries of a solution before attempting to reach it. For example, of what order of magnitude must the solution to a computational problem be? In the 100's, 1,000's, 1,000,000's? What are the facts that the solution to a mystery must account for? For what actions and traits does a theory of Hamlet's character account? In addition, what broad categories of solution are appropriate? There are times, for example, when a fantasy or magical solution is called for, others where a more realistic answer is needed.

7. Another area in which the learner can probably be helped concerns the temporal aspects of problem-solving. Again in the absence of relevant research, points of emphasis can only be suggested. For one thing, problem-solution cannot be hurried. Ideas can be encouraged and welcomed, but they will come in their own time. Thus time for reflection is essential, and emphasis on speed of response can hardly be regarded as an unqualified good. Time for reflection has the additional advantage of enabling the learner to detach himself from the problem after a period of intense engagement with it and, from a distance, come to a new or broader view of it.

Not only must the child learn when to stop and disengage himself from the problem, he must learn also when to stop one approach and try a new one. (Persistence is discussed in chapter I of this report.) In the case of nonschool problems, indeed, he must know when to stop and give up the problem. Again, he must learn to know when to stop because he has solved the problem, or when to stop to test the work he has done. In this connection, it is interesting that a major problem in work with computers is how to deal with stop orders.

8. Tests of the correctness of his thinking are an important part of the equipment of the problem-solver. Tests of the correctness of arithmetical problems or of logical deductions are familiar, but tests must be found for other kinds of problems as well. For example, the definition of boundaries of the solution is an aid in testing solutions as well as in arriving at them. Does the solution fall within the required limits of magnitude? Does it account for all the facts? The set to find discrepancies and difficulties can also be used to set solutions as well as to solve problems. Other tests will suggest themselves in connection with specific classroom problems. Tests the learner himself can employ make him independent of the teacher in a significant respect and can presumably carry over to a nonschool situation where checks by the teacher are lacking.

Perhaps more important for the training of problem-solvers than any of the particular skills enumerated here is the knowledge that there are ways of helping oneself to solve problems. Of course, not all devices are equally useful for all children. Taking time for reflection, for example, is very likely more difficult for the impulsive child than for the reflective one (cf. discussion of cognitive styles). Thus an important part of education for problem-solving is helping the individual child to find his own methods for improving problem-solving.[3]

Creating

It is not easy to make recommendations about cognitive skills, the development of which would promote so little understood a phenomenon as creativity. The suggestions to follow are presented as the most tentative hypotheses, and are derived largely from anecdotal accounts of creative work.

Prerequisite to "training for creativity" is the recognition of it when it occurs in the often modest forms in which it is encountered in the classroom. For purposes of the present discussion a creative idea, solution, question, or understanding will be defined in terms of two characteristics: its elegance and a particular kind of novelty. Elegance can be recognized by the simplicity of the production, its harmoniousness, its "just-rightness" in relation to the given problem —none of these being terms the present writer would care to define. Novelty is here intended to refer to novelty *for the individual learner.* Although young children do not ordinarily contribute new proofs or new interpretations of literature or new formulations of scientific problems, their products may be new with regard to their own conceptual framework, their own assumptions (tacit or explicit), their own way of thinking. Of course, not everything new a child learns can be called creative. If he learns the meanings of 10 new words—indeed if he figures out their meaning from knowledge of related words—this achievement though laudable is not here considered creative since it fails to break with the learner's previous way of thinking. Creativity then is defined here not by an external standard but by reference to the child himself; not by achievement, since other thinkers are likely to have got there first, but by process, by its relation to the child's own thinking.

1. The above definition of creativity suggests one condition of it to which the learner can be alerted and which he can be helped to make a part of his approach to learning. Creativity, it has been

---

[3] Although attitudes that predispose toward learning are discussed elsewhere in this report, a word will be said here about attitudes toward learning and thinking themselves. Again no attempt will be made to solve a problem, but merely to indicate that there is one. The child discovers to varying degrees, for example, that there are things to think about in his world and perhaps that thinking about them is fun. He can come to regard his mind as a powerful instrument in the use of which one can acquire skill, or he can fail to do so. He can come to regard himself as a source of understanding, a process doubtless facilitated by the use of Socratic procedures. These and other aspects of the child's attitudes toward his own thinking merit exploration on the hypothesis that they could make an important difference in the success or failure of training a child for self-education.

suggested, involves overcoming the restraints, tacit and explicit, of one's own assumptions. This means that the practice of making explicit and examining one's assumptions might encourage creative learning. The practice could be developed in any subject area. The use of the "counter-intuitive" case—which is discussed in a different connection in this report—is an example of the kind of training that might help.

2. In connection with problem-solving, one procedure put forth for overcoming blocks was that of subjecting oneself to varied stimulation which might suggest something that will lead to solution. In the case of creative thinking, to the extent to which one is not dealing with set problems, an opposite procedure might be more helpful —an actual withdrawal from stimulation so that one is better able to stop and listen to the ideas that occur.

3. Creating, as it has been described up to this point, has been considered a matter of letting happen what will happen, of welcoming the ideas that come. But it also has a more active phase. Once a promising idea has occurred, creating demands all the measures described above under Problem-Solving to test it, develop it, relate it to what else is known.

Since creating is so closely related to intuition, the discussion of intuition that follows will be relevant to our present issue.

SENSITIZATION AND ACTIVATION OF COGNITIVE SKILLS

Richard Crutchfield

Cognitive skills for acquiring knowledge, understanding phenomena, solving problems, and creating new forms of ideas emerge gradually during the normal development of the child as a consequence of successful coping with his environment and of his formal schooling. But these skills, though existing in every school child in at least rudimentary form, are rarely brought to their optimal level of development. This is especially true of the more complex skills instrumental to problem-solving and creative thinking, which are sorely neglected in most current educational practice.

But it is probable that the child is usually not sufficiently sensitized and set for the active use of the skills that he does possess, in whatever degree, nor is he adequately trained in how to use them. It is not enough, for instance, that an individual merely be *able* to generate many new ideas; he must also have a highly aroused general set or propensity to do so, especially when confronted by cognition tasks which require it. And he must know *how* best to apply his skills to the task.

Sensitization and activation of the child's cognitive skills occur mainly through repeated experiences of their successful use by the child. Current educational practice is seriously deficient in providing the child with these experiences. Principally, this is due to the *sheer paucity* in the curriculum of tasks which call upon the child to engage in genuine problem-solving and thinking. The typical school, to say nothing of the "real life" environment outside, seems almost to be managed so as to place minimal demands upon the child actually to think, thus effectively depriving him of opportunities to think.

Moreover, even where the schoolwork does call for the application of cognitive skills, the child too frequently fails to gain an authentic sense of successful achievement in their use: (1) The tasks on which the child works are often too easy, requiring too little of his potential capacity. Failing to be "stretched," the skills do not grow, indeed they may tend to atrophy through disuse (the muscular metaphor may not be entirely farfetched!). (2) The tasks often involve what seem to the child to be meaningless, repetitive exercises of low-order skills; after such prolonged trivial misuse, he is convinced these skills are of no value. (Endless drill in diagramming simple exercises is not likely to enamor the child of his analytical powers or of the value of analysis.) (3) Moreover, reward for "cheap" success in these easy and repetitive tasks gives the child a spurious sense of competence in his skills. It is a common observation that a potentially gifted child who has found it very easy to surpass his mediocre classmates in low-order mental work and has been excessively rewarded for it may later on in school find it difficult to move ahead to the mastery of higher-order skills demanded of him. Too often the child is permitted merely to listen and to go along passively in the group, not being required actively to demonstrate the skill that he is presumably being taught. Thus the teacher often fails to get necessary feedback from the child in order to evaluate and direct his progress. (4) The opposite side of this—and the more detrimental—is the failure of full, prompt, and informative feedback to the child concerning his cognition skills. The mere fact that he gets the "right" answer or passes the test may tell him little about the adequacy of the skill he is seeking to perfect. In any case, size of classes is usually too large to permit the amount of highly individualized, detailed, and discriminating feedback that is best for the painful process of guiding and building a complex skill. Thus the child is usually unable to determine just how much and in just what way his skills contribute, or fail to contribute, to his performance on the tasks, and he is thus unable to establish valid ways of evaluating his own skills.

In short, the child in the all-too-typical school situation is being expected to develop efficient cognitive skills, such as those in problem-solving, under conditions where he is offered few opportunities for actual practice of the skill, where the practice he does get is likely to consist of tasks that are too easy, too repetitive, and seem meaningless and trivial to him, where he is often rewarded for low-level performance on these tasks, where he can often just passively listen instead of actively trying out the skill, where he gets incomplete and delayed evaluative information about how well or poorly he is doing and little specific indication of just what he is doing right and what wrong. It is clear that no respectable athletic skill could be developed under such bizarre handicaps (nor would any coach countenance them), and it is doubtful that any complex cognitive skill could be so developed.

This diagnosis of some of the difficulties besetting the adequate teaching of cognitive skills points directly to a number of positive instructional steps that can be taken to remedy the difficulties and to kinds of research studies which are required in order to implement and to evaluate the outcome of these instructional steps.

1. In the sweeping reconstruction of curriculum materials currently in progress, a good deal of emphasis should be put on designing the materials deliberately in such a way as to demand the exercise of complex cognitive skills of problem-solving and cognitive thinking to a degree compatible with other curricular aims. It seems likely that virtually all curricular materials—regardless of field, topic, or level—can be designed so as to involve whatever specific cognitive skills may be desired without detriment to the orderly presentation of the curricular content. New and existing curriculum materials should be studied to determine how best to build the teaching of cognitive skills into them.

2. Once such curriculum materials are available, they should be studied as they are tried out in the schools, with particular emphasis on a detailed observational analysis and evaluation of children's performances in the various skills. To perform such an evaluation, we will need to design and develop entirely new types of tests of complex cognitive skills. Such tests should be able to (a) measure all of the principal skills involved in problem-solving and thinking, (b) assess degree of transfer of skills from one curricular field to others, (c) measure individuals of various ages and school levels, and —most difficult of all—(d) measure separately other levels of sensitization and arousal of the skill as manifested in the individual's generalized propensity to employ the skill in cognitive tasks, and the level of the skill capacity possessed by the individual. No adequate tests of complex cognitive skills fulfilling these specifications now exist. Their development is a prime prerequisite to research on the training of cognitive skills.

3. Better teaching techniques for the fostering of cognitive skills must be developed. In particular, the child should be helped to identify, discriminate, and understand the nature and function of the skills involved in various kinds of cognitive tasks. He should be shown what can be done in problem-solving and creative thinking through the effective use of these skills. Each child should be brought to participate actively in practicing and exploring these skills, principally through the experience of his own working through a great volume and variety of problem-solving and creative thinking tasks. (Thinking should be a participant sport.) In all of this work, teaching techniques and instructional materials should be aimed toward providing immediate maximum informational feedback to the child concerning the results of his work, the effectiveness of use of his skills, the nature and sources of deficiencies in his performance. It is of paramount importance that feedback be tailored to fit the particular responses of the individual child, rather than

being diffusely aimed at an entire classroom. This points to the need for development of more powerful and individualized tutor-learner feedback techniques than are now available.

4. In curriculum materials and instructional efforts great stress should be placed on the transfer of cognitive skills. The child should be brought to understand the wide applicability of these complex skills to other subject-matter problems and to other fields. In other words, he should be deliberately taught to transfer. The teacher must strike a balance: she must teach the skill in a sufficiently delimited manner so as to insure its being fully mastered, but she must also teach it as imbedded in a complex task, so as to insure its later transfer to similarly complex tasks where the skill is ultimately to be employed. How to achieve such an optimal balance is an engaging problem for research.

5. Finally, attention must be given to the development and refinement in the child of an indispensable, overmastering cognitive skill—the skill of organizing and managing the many specific cognitive skills and resources one possesses for effectively attacking a problem. It is in part the possession of such a master skill that distinguishes the truly productive thinker and creator from the merely talented person. This governing skill has many aspects. It involves an understanding of the nature of different types of problems and of the appropriate skills required in their solution. It involves the grasp of general strategies of problem-attack, the use of a "planning method" for breaking the problem up into manageable sequential steps. It involves a highly developed sense of timing—an inseparable attribute of almost all skills—and an ability to assemble component skills in an optimal pattern. It involves an ability to be flexible and adaptive in the use of one's often competing skills—being able to be alternatively intuitive and analytical, engaged and disengaged, serious and playful, creative and critical, seeking for complexity and striving for simplicity. And above all, it involves an understanding of how to compensate for deficiencies in certain of one's skills and how to exploit one's special talents, not only in the choice of the mode of attack on a problem, but also in the very choice of problems to work on.

The teaching of this master skill poses challenges both for educational innovation and research. One obvious implication is that the child should receive a considerable amount of training in dealing with complex thinking problems, problems which incorporate heterogeneous materials and techniques—often transcurricular—and demand an effective mobilization and integration of one's diverse cognitive skills and resources for a successful attack on the problems. It can be argued, though evidence is scanty, that only through such direct training experience on highly complex problems can the individual come to develop the requisite skill in solving them. This departs, of course, from the more usual instructional concentration on problems which are homogeneous in content and techniques.

An urgent research requirement in this connection is the invention and experimental study of a large population of the kinds of complex thought problems needed in such training. At present very few good problems of sufficient scope and variety exist. A major effort should be directed at developing such problems and exhaustively analyzing the behavior of children on them.

As a contribution to this research, there should also be undertaken a basic conceptual analysis of problems, an attempt to clarify the psychological and ecological dimensions according to which problems can be functionally classified. This kind of taxonomic and morphological study of problems would make possible a more rational and representative selection of problems to be used for teaching and experimental purposes; and it would also illuminate interesting empty niches in this problem-space, leading to the construction of special kinds of problems not now existing.

Another significant educational implication of the training of the master cognitive skill is that account must be taken of the brute fact of individual differences in basic capacities among children. The educational aim should not and cannot be to raise every child to an equivalent level in all of his cognitive skills. The aim should be to maximize for each child that optimal individual *pattern* of skills that will enable him to think effectively in a "style" most compatible with his own idiosyncratic cognitive and tempramental makeup.

Various current educational experiments on the direct teaching of complex skills in problem-solving and creative thinking point both to the ultimate promise of such approaches and to the urgent need for vastly increased research on these methods. One major example is the "inquiry training" for elementary school children, being investigated by Suchman of the University of Illinois. The aim is to train the children to be able to discover for themselves explanations for unfamiliar phenomena (shown to them in films of simple physics demonstrations). In the class setting, the children are encouraged to ask questions and formulate hypotheses. The teacher provides information and corrective feedback to these questions, but in such a limited manner as to force the children to take successive steps in thought until they themselves discover the explanations.

A quite different approach is illustrated by the work of Crutchfield and his colleagues at the University of California, Berkeley. The aim is to promote *generalized* problem-solving skills in fifth- and sixth-grade children, skills which are likely to be applicable to a wide range of problems in many different subject-matter fields. The written and pictorial programed-type training materials were designed to accomplish several instructional purposes:

1. To demonstrate and emphasize in problem-solving the value, necessity, and techniques of identifying and defining a problem properly, of asking questions and taking time for reflection rather than leaping to conclusions, of looking carefully at details and searching for discrepancies, of generating many ideas and not fearing to come up with what may seem "silly" ideas, of looking everywhere when stymied for possible clues and sources of ideas, etc.
2. To give the child an opportunity to generate his own ideas and to become more familiar with his own thought processes and individual cognitive style.
3. To give the child immediate and frequent feedback to his ideas in the form of good examples of fruitful questions and hypotheses, either as confirmation of his own ideas or as helpful guides to his thinking.
4. To allow the child to "participate" in the solution of problems with a pair of curious and imaginative children who serve as identification-models.

The training materials have been written in a free adaptation of the *programed-instructional form* in an effort to capitalize on several crucial advantages of this method: (1) individual self-administration, permitting freedom from direct group and teacher pressures, permitting individual self-pacing and freedom from interruption of one's own thought, etc.; (2) immediate feedback for each child contingent upon his own individual responses; (3) the requiring of active involvement by the child in the materials; (4) the providing of greater scope for exploitation of and accommodation to the divergent and idiosyncratic responses of the child; (5) built-in diagnostic tests or "indicators" of the sequential progress of the child's thinking, of the specific difficulties being encountered, etc. Such book-form programed materials can be administered in a flexible manner by the teacher as a supplementary part of other classwork, requiring little or no direct intervention by the teacher and no special training of the teacher in the use of the materials.

Results from the first major school tryout of these materials indicate that they produced substantial increments in the performance of the trained children on a variety of criterion tests of problem-solving and creative thinking.

A substantial research effort should be devoted to the improvement and extension of these training methods. The programed materials need to be pushed and tested to their maximal limits of use. They need to be extended both upward to the junior high school and downward to the fourth grade and as far earlier as it is possible to go with young children by simplifying the verbal materials and expanding the pictorial. They need to be extended to include a greater variety of problems taken from different disciplines so as to increase the likelihood of generalized transfer of these skills to all school curriculums. Particular attention must also be given in the programed materials to ways of strengthening the child's positive *attitudes* toward problem-solving and creative thinking and toward himself as an effective problem-solver and thinker. In this connection research is needed in the development of adequate test instruments, now unavailable, for evaluating these attitudes in the child toward problem-solving and creative thinking.

TOWARDS A DISCIPLINED INTUITION

Jerome Bruner and Blythe Clinchy

In virtually any field of intellectual endeavor one may distinguish two approaches usually asserted to be different. One is intuitive, the other analytic. There are many ways in which the difference can be characterized, depending upon the particular field; but in general, intuition is less rigorous with respect to proof, more visual or "ikonic," more oriented to the whole problem than to particular parts, less verbalized with respect to justification, and based upon a confidence in one's ability to operate with insufficient data. We will not attempt a more discerning definition of intuition at this juncture. We will assume, for the moment, that the distinction is useful in characterizing approaches to intellectual work.

The solutions and discoveries of scientists and scholars are often at least partly intuitive. Science and history as written are the Sunday activities of the scientist and the historian in contrast to their weekday activities. It is also true that the leaps that man takes on the basis of insufficient evidence constitute the principal source of error in his intellectual activity. It is for this reason that thinking men, before stating their conclusion badly, shift to analysis to determine whether they were right or wrong in their short-cut approximations. Precise and demanding analysis is the guarantor against error.

Young children can be said to know things without being able to put what they know into words. This is where we find them when they enter school. If we take it as axiomatic or obvious that in teaching children we take them where we find them, it is quite plain that learning and teaching must start from some intuitive level. This may be true not only of young children entering the educational establishment for the first time, but of anybody approaching a new body of knowledge or skills for the first time. Only a romantic pedagogue would say that the main object of schooling is to preserve the child's intuitive gift. And only a foolish one would say that the principal object is to get him beyond all access to intuition, to make a precise analytic machine of him. Obviously, the aim of a balanced schooling is to enable the child to proceed intuitively when necessary and to analyze when appropriate.

It is with these considerations in mind that we turn to the question of how one brings a child to his full analytic powers in particular disciplines while at the same time preserving in him a robust sense of the uses of intuitive thinking both in intellectual activities and in daily life.

Features of Intuitive Thinking

Better to assess the nature of the training that might nurture intuitive thinking we turn here to a brief summary of some of its features that seem of particular importance in various intellectual disciplines.

Activation

Though it seems banal to say it outright, the first requirement of any problem-solving sequence is to get started, to get behavior out where it can be corrected, to get the learner committed to some track, to allow him to make an external summary of his internal thought processes. One of the first resistances to be overcome in problem solving is inertia—"just sitting there," neither thinking much nor doing anything. This is not to say that reflectiveness is not a virtue at some point in the problem-solving sequence, but reflectiveness serves better once there is some commitment to direction. Often a first precise move is not apparent in solving a problem or in getting an idea straight. Rather, one has the sense of a possible or estimated way of getting started. It is almost a kind of locational activity, determining what part of the forest to work in. It is in essence an imprecise opening move that is involved.

Confidence

While one must have some degree of self-confidence before one can make a start on a task, the act of starting itself increases one's confidence in the ability to carry the task through. Gifted teachers report often that their first task is to give students the notion that their minds can be used as instruments. The initial confidence of having made a start and a sense of the problem's corrigibility (which we shall discuss below) permits the learner, we would guess, to move on to the task of formulating hypotheses on the basis of partial evidence.

Visualization

The paradigm or limit of most intuitive heuristics is direct perception. When a person says that at last he "sees" something, often he means that he senses it in a visualized or sensory embodiment. It is this kind of embodiment that often permits directness of grasp or immediateness of conclusion. But it should also be clear that a visualization may often be inappropriate. In any case, save in the rare instances of intuitive geometry, it is impossible to have a rigorous proof of anything when it is in an ikonic form. Yet, plainly, the visualization indicates in many cases what one must do next to get it proved. "Seeing" something, unfortunately, carries with it the often false assumption that something is as plain as seeing a thing out there. This is, of course, a danger of unbridled intuition.

Non-Verbalizability

It is characteristic of intuitive procedures that the person is not able to give much verbal justification of why he is proceeding as he is or why he has made a particular discrimination. In this respect, the behavior is not fully under the control of the learner in the sense of being translatable into the language necessary for summary, transformation, and criticism. Justification in words of symbols or in manipulative proof is at least amenable to correction and closer analysis. But generally, the pure intuitive act is not so subject.

Informal Structural Basis

It is often assumed that intuitive thinking is somehow free and ungoverned. Surely this is a mistake. More likely, what we speak of as intuition is a shortcut based on an informal and often inexpressible structuring of a task. The structure, so-called, may be nothing more than a sense of a connection between means and ends or of some notion, difficult to clarify, of "belongingness."

Partial Use of Available Information

Whether the person uses a heuristic involving visualization or some other shorthand way of summarizing the connections inside a set of givens, he drastically reduces the range of things to which he attends. This narrowing of focus involves a kind of risk-taking that requires not only a certain amount of confidence, but also a kind of implicit rule for ignoring certain information, again a risky prescience about the nature of a solution or the kind of goal one is looking for. This is what imparts directionality to the subject's problem-solving under these circumstances. The risk, of course, is in getting in so deep that it becomes hard to disengage and cut one's losses.

The foregoing are some of the aspects of intuition. We do not suggest that they occur *only* as aspects of intuition. This is a matter for closer analysis at some later time. Here we are frankly using a rough approximation to get on with the task. Analysis should provide the correction, and to that subject we turn next.

Analysis and Intuition

One can begin by noting that in a certain sense the opposite of the above characteristics holds—but only within limits. Analysis in a well-trained problem-solver can be just as activating as intuition, but in many cases it takes a hunch to figure out first where the analytic tools should be applied. Similarly, analysis and a sense of one's capacity to apply analytic procedures increase a problem-solver's confidence. Yet, at the same time, it is often a first order approximation, a non-rigorous proof showing that one is in the right domain, that gives one the confidence to go on with exacting and sometimes tedious analytic procedures of proof. Analytic, step-by-step proof requires a far more formulated structural sense of a problem, though the well-trained analyst may not be conscious of his structural assumptions while he is carrying out his task of verification.

The virtues of intuition as an opening approach to a problem are probably self-evident. One's first intuition, when faced with a new body of material, is often nothing more than a sense of "wrongness" or "rightness." I look at a list of projects planned for first-graders learning about the Eskimo, for instance, and it strikes me at once that there is something wrong with some of the projects and something right about others. Putting plants in the icebox is right, but building a styrofoam igloo is wrong. By letting each item "speak" to me in a general way, I can categorize each project as right or wrong. But if I stop here, I am nowhere. Now it is time for analysis; I compare the lists, and, finally, the sense of wrongness is printed out as, say, "heavy-handed verisimilitude." Intuition, to be fruitful, must carry this sense of incompleteness, the feeling that there is something more to be done. It is most successful when it can be backstopped and disciplined by more rigorous techniques of problem-solving and problem formulation. For unless it operates in phase with more rigorous and verifiable methods, its deficiency is some combination of looseness and incorrigibility. Take for example the good intuitive formulation that, in order for international relations to exist, there must be some kind of exchange of goods and services between nations. It poses a problem in an interesting way. But if one stops with such a loose formulation, one is likely to miss out on the important boundary conditions that constrain this formulation. It fails to distinguish, for example, between a system marked by direct barter and one that involves a "delay" mechanism for balance of payments such as an international bank. Moreover, it fails to specify the manner in which a network of exchange can constitute an "internal market" of nations such as the British Commonwealth or the Common Market. The intuition, to be fully effective, must carry with it a way of analyzing exchange that goes beyond the first sense of economic mutuality. Many students who encounter such ideas as tariffs, economic relations, and the rest have only the analytic apparatus and none of the general intuitive feel that is needed to put the pieces into a coherent and understandable picture. Contrariwise, the student who rests solely with the idea of mutuality of trade has only the general image and none of the sense of how the mutuality works itself out in the complexities of the real world. The issue here is between understanding in an approximate way—having a sense of something—and being so lost in the particularities that the overall meaning of the relations among a set of facts is lost.

The issue is more complex than appears on the surface. For it does not hold that intuition is always vague and analysis always rigorous. It was not until quite recent years, for example, that Euler's famous "proofs" were rendered into rigorous form. In their original version many steps were left quite intuitive and, in a rigorous sense, untested and untestable. Yet much of mathematics was built upon them, and it took a century of living with the intuitive proofs for sufficient axiomatic skills to be developed to carry them to a point of rigor. One can extend this to mathematical understanding in the child. A young student may come to a clear understanding of factoring and prime numbers by visualizing them in terms of the way in which quantities of beans can or cannot be laid out in columns and rows. His understanding is clear but it is limited; it is difficult for him to relate it to other mathematical properties that cannot find an embodiment in the imagery that he has chosen to represent his ideas. Moreover, it is hard in any instance for the child, dealing with a moderately large number, to prove by bean arrangement alone that the number is or is not factorable.

But now take the case of intuition in a sphere where verifiability is not so accessible and where, possibly, it is of a different order. We could dip deep into the folk-culture, for example, and take two popular comic strips—*Pogo* and *Little Orphan Annie.* Either can be read in terms of "what-happened-that-day." And probably a fair number of children read the strips in just that way. But one can also read each with a sense of its form of social criticism, its way of depicting human response to difficulty, its underlying assumptions about the dynamics of human character. One child is able to sense the underlying paternalistic authoritarianism of Little

Orphan Annie or the gentle irony of Pogo with respect to authority. Another can give an accurate account of what went on over a period of a week in each strip. Surely we cannot call the second child more precise than the first; there is something he is not understanding at all. It is like those people who recount conversations in the "he said, she said" mode with no grasp of what in fact at some deeper level people were saying to each other. What one would hope to do for the child who had grasped the intuitive distinction between the two cartoon strips is to take him on to a richer understanding of what he had understood in this restricted domain. If his reading powers were up to it, we might lead him now to a reading of Jonathan Swift on the one hand and *Richard III* on the other. (Again, one could not hope at the outset for a deep mining of the rein of irony in *Gulliver*, not for much of a grasp of Richard's contempt for man on the other.) Or possibly, in contrast to Daddy Warbucks, one would want to give the image of a type who, by his largesse, ends in a shambles of isolation—perhaps *Gatsby*. Whatever one chooses as the next episode in deepening a flickering intuition, it is certainly in the direction of extending it and refining it by exposure to new material.

Unexploited intuition that goes nowhere and does not deepen itself by further digging into the materials—be they human, literary, scientific, mathematical, political—is somehow not sufficient to bring the person to the full use of his capacities. Intuition is an invitation to go further—whether intuitively or analytically. And it is with the training of people to go further in this way that we are concerned here.

Training of Intuition

Let it be said at the outset that nothing is known about the training of intuition and that very likely we are still too unclear about what is intended by the word to devise proper educational procedures. Yet paradoxically enough, there are features of the intuitive method that are fully enough appreciated and recognized —in an intuitive way, to be sure—to merit some consideration from the point of view not only of their educability but also from the point of view of how they may be linked with the kinds of "follow-up" acts that permit the exploitation of intuition.

Legitimization

Often, one of the first impressions that a child gets in school is that one proceeds by quite different techniques than one had hitherto used. There is a kind of damping down of fantasy, imagination, clever guessing, visualization, in the interest of teaching reading and drawing, writing and arithmetic. Great emphasis is placed upon being able to say what one has on one's mind clearly and precisely the first time. The atmosphere, as one of the members of the conference put it, emphasizes "intraverbal skills"—using words to talk about words that refer to still other words.

Much has been said—much of it nonsense—on the need for building upon what the child already knows when designing a school curriculum. Start with the familiar friendly trashman, for example, before moving on to the rather more bizarre "community helpers" among the Netsillik Eskimo. However one feels about this question—and it seems doubtful to us that children really find pediatricians more interesting or even more comprehensible than witch-doctors—we are suggesting that transfer of skills the child has learned may be much more crucial to education than transfer of content. There is enough research now extant on children of the school-entering age to indicate that one can indeed build upon the skills that they bring to school with them, skills which, by our earlier definition, are clearly intuitive in nature. Consider a few of them.

We have commented earlier that intuitive operations precede highly descriptive or symbolic ones, and that one of the major forms of intuitive operation is somehow visual in nature. How can instruction help the child to exploit his visualizing skills and, more important, to begin to shape them into more rigorous instruments?

The young child makes no clear distinction between an object seen, the function to which it can be put, and the affect it arouses. Perhaps for this reason he has strong opinions as to which of two lines is angrier, wearier, or more exuberant. This sort of affective summarizing can be the basis for later discriminations between elegance and clumsiness in visual representations. Surely he should be allowed to practice these skills out in the open where they can be subjected to criticism.

There are numerous testing procedures which require the subject to decompose figures into their component parts—the Witkin test, for instance, and the Goldstein-Scheerer procedure. Such exercises are rarely used as instructional devices except in banal form as part of the "reading readiness" curriculum. A Danish investigator, Martin Johanson, has shown that they can be used in a more sophisticated fashion: he is able to improve his subjects' understanding of solid geometry by giving them practice in decomposing complex solid forms into their component simpler solids. And various illustrators, notably the Dutch engraver Escher, have provided beautiful exercises in ambiguous decomposition of complex pictures.

There are a number of techniques which are used to test a child's recognition of transformations in images. The FLAGS procedure, for example, asks the child to choose, from a variety of complex flags in a variety of orientations, that one which matches the original. We would do well to train the child to recognize transformations rather than simply to test whatever facility he may have haphazardly acquired. We suspect that recognition of transformations is trainable: consider, for example, the fact that our children, growing up in a world thick with geometrical and mechanical constraints, early and permanently outstrip bush children in their ability to deal with visual mechanical problems.

Marie Montessori long ago described procedures for teaching children to make subtle sensory discriminations. Much could be done by way of training children to order differences which they discriminate, not simply in linear arrays but in multi-dimensional arrays. There is little question that techniques such as the game of tic-tac-toe played on Cartesian co-ordinates (Madison Project) and multiple-classification games of a highly concrete nature do in fact enrich visual subtlety.

The child's graphic representational skills are highly diagrammatic in nature. They will soon become quite stereotyped and eventually take on conventional forms of representing "reality." In the first few years of schooling, it would be worth while to try to develop to some richer level the kinds of subjective diagramatization that he already has within his grasp. There are conventional art forms that he, perhaps better than adults, is capable of penetrating—where size connotes centrality, for example: he produces pictures in which the teacher is enormous in terms of the space she occupies on the page, and little sister is scarcely more than a dot. Letting the child sense at the outset that this too is a permissible mode of representation and not simply a "cutely childish" form of drawing may provide him not so much with a new skill but with a sense that his old ways of knowing are neither indecent nor irrelevant. From here one can surely take the child to forms of graphic representation that discipline and use the forms of representation he has to communicate to other children.

The child who prays on the way to school, "Please, God, don't let them do Jules Verne in English class," seeks protection not from the subject-matter of schooling, but from its methods. He does not want a book that he has grasped intuitively and lovingly to come under the near sadistic dissections of his English teacher. So often the intuitive approach goes underground to become part of what David Page calls the "secret intellectual life" of the child. The result, one suspects, may not be the analytic facility aimed at by the educator but a loathing for seemingly arbitrary analysis and an uninformed intuition. The problem is most severe perhaps in the early school years, if only because prevention is so much easier than cure. But it is likely a persistent problem. One wonders, for example, whether the keen social intuitions of the junior high school student could not find their way into the social studies curriculum or into his reading of literature in school.

Allowing the child to use his intuitive faculties is not only a practical matter of exploiting available resources. It is also a matter of honesty. The overanalytic models so often presented to children in their textbooks on math and physics can lead to a confusion of proof and process. (See Kessen's paper on this point.) The Sunday hindsight physics of the textbook is often a far cry from the messy weekday activity of the real-life physicist and makes physics seem more remote than it need be; children need models of competence perhaps, but surely not of omnipotence. By recognizing the legitimacy of intuition as an intellectual operation, schools could spare their students the painful relearning that is required of them later when, for example, they "really get into" physics and are required not to prove a given solution but to find a solution. For example, find if you can any similarity between geography as presented in the usual textbook and geography as practiced by geographers. The problems are presented as solved at the outset. The child is then asked, so to speak, to consider how the "authority" arrived at his solution. In a geography text we will find at the beginning of a chapter the statement, "The world can be divided into temperate, torrid, and frigid zones." Virtually the whole of the effort in the paragraphs that follow is given over to making it seem as if this distinction is obvious. Many children, we are convinced, are left with the image of an earth in which one can find border signs which read, something of the order, "You are now entering the temperate zone," put there by some benign authority in league with the textbook writer. The problem, how to characterize the surface of the earth in terms of regions, disappears and geography is converted into a combination of tongue-twisting names in a gazeteer and some rather puzzling maps in which "Greenland looks much bigger than it is." What is lost in this arbitrariness is a development of a sense of problem in the child.

Constraint and Intuition

We have seen a teacher introduce a fifth-grade class to the game of "hidden numbers." Before the pupils enter the classroom, the teacher writes a set of numbers on the board and covers them up. He gives the students a few clues about the set—for example, that it sums to less than 20. It is up to the class to ask further questions about the numbers in order to infer what they are. In fact the game was a primitive version of algebra carried out in an intuitive fashion. One could not help but be struck by the way in which the children came to recognize the constraints of the information they had already received in guiding their guesses as to the nature of the numbers.

The same procedure is readily transferred to other spheres of intellectual activity. There is an almost infinite variety of games that can be played with an episode or a period of history. Indeed, even so superficially unpromising a subject as geography can be converted into the form of making inference from partial information—a central feature of intuitive procedure. What is needed at this juncture is careful observational research on what children actually do in learning to play such "games" skillfully and in what ways they can be led to transfer their skills in a general way to other fields.

Most important of all is the basic question as to whether training of this kind might lead the child to greater confidence in intellectual activity generally. After all, the great question in training a mind to operate beyond the sphere of intellectual involvement of a formal kind is precisely to train it to reach conclusions on the basis of insufficient evidence and to know how to inquire after new evidence in order to cut down the conjectural nature of the conclusions he has reached.

Going Beyond the Information Given

Most human beings are unaware of how much information they actually possess on a given subject. Put more technically, when information is organized in terms of some generative model, it turns out that there are many other things that follow from it in a way that verges on redundancy. While this is usually recognized in more structured subjects such as mathematics (we all grant that the statement "Alice is taller than Mary; Mary is taller than Jane" implies that Alice is taller than Jane), it is not so generally recognized that any connected body of knowledge contains such redundant implications, even if in a less strict sense. What does one know, for example, about situations in which a group of people are being taxed by officials over which they have no electoral control or no other recourse? Surely, something more than that a popular cry of the Revolution was "No taxation without representation."

Again we feel that there are many exercises that can have the effect of leading the child to recognize not only that he has a string of facts but that, put into some order, they generate more facts. This is the notion behind much recent urging that curriculums be organized around the idea of the structure of a discipline. But the matter goes well beyond that. Indeed, well short of a "discipline," most collections of givens have about them the character of a substructure which, when sensed, provides the way of going beyond the information given.

It has often been said that structural considerations of this sort are more relevant to sciences and mathematics than to literature or history. It seems to us that this is likely a misunderstanding of what is meant by structure. If a novel is put together with no necessary relation between one set of events and others, then surely it is a poor novel. Consider, for example, the crew of the Pequod in *Moby Dick*. Why are they all pagans, not a Christian in the lot? What if they had all been New Bedford Puritans—even libertine Puritans? It is this pagan crew that searches the white whale to the deepest part of the sea. Why is the whale white and the crew pagan? And what manner of man would Ahab have to be? What other kind of captain could have commanded such a quest? Melville wrote to Hawthorne that this was a wicked book, suggesting indeed that it was concerned with subversive matters. We are not proposing that children be turned early toward the symbol-chasing proclivities of the new criticism. Rather, the object here is to suggest that in this work of art there is something that lies beyond the mere narrative.

Consider the nature of a play. Can the third act drift off independently of the first two? Likely not. A student who has pondered the first two acts should be able to write a reasonably appropriate third act—though it may differ from the original. In comparing his version with the playwright's, the student should become aware of subtle constraints that he did and did not take into account. Here "error" can be extremely informative: Was the student carried away by the desire for a happy ending or for one that carried a bang when a whimper would have been more appropriate?

Heuristic Economy

There are ways for using the mind in a fashion designed to save work, to make seemingly difficult problems easier, to bring a complicated matter into the range of one's attention. One rarely speaks of them, and surely there are no courses for teaching them. One learns to make little diagrams or to use a matrix. Or one asks oneself whether the solution he is tending towards will have a magnitude that is somewhere within the range of magnitudes in which the correct solution lies. Or one asks, encountering a new problem, whether there is anything like it one has encountered and solved before. Or one asks where one is trying to get. Or asks, how would I act if I were a molecule? Or, before doing the experiment we ask what would we know if it came out in one extreme way as compared to another. All of these are ways of honoring the fact that man has highly limited capacities for attending to things, for remembering them, or, in general, for processing information.

In general the difference between two people of equal IQ, one of whom is bright and the other stupid, is that the first has learned how to use his limited capacities by conserving them, by not straining after gnats, by cutting his losses early, by taking a little thought before committing himself to a long chain of reckoning. Most such economical heuristics are subject-specific—or seemingly so. But some experiments indicate that surprisingly large gains can be scored by teaching them even in a manner not related to specific subject matters, as in the experiments of Crutchfield. What is quite plain is that students can be trained out of their use by schoolmasters who regard such techniques as forms of cheating. They are the ones who value precision in procedure more highly than solution of a problem. Housewives are told to use the fruits of time and motion studies in refining their bed-making procedures. Why should efficient algebra be regarded as a sin?

We would suggest as a start that any new curriculum contain a syllabus designed to teach the economical tricks of the trade as early and as effectively as possible. We should also like to propose that special research be undertaken to devise and test certain "transcurricular" courses that have as their object the teaching of such methods. Efforts at inquiry training, at teaching students to attend to and use the cues that are available, and the like have proved sufficiently successful to warrant an effort of this sort. If nothing else were accomplished by such a program, at least it would signal that it is not disgraceful or lazy to save one's heels by using one's head.

Let one thing be clear in conclusion. Our urgent proposal that the ways of teaching intuition be studied with great care comes out of a conviction that intuition is not only fruitful but necessary. The young child approaching a new subject or an unfamiliar problem either has recourse to the less than rigorous techniques of intuition or is left motionless and discouraged. So too the scientist or critic operating at the far reach of his capacities in his chosen field. The proposal does not assume that intuition and its uses should be encouraged in untrammeled form; rather it suggests that intuitive skill be used and exploited and that it be buttressed by more rigorous followups. If a man is to use his capacities to the full and with the confidence that fits his powers, he has no alternative but to recognize the importance and power of intuitive methods in all fields of inquiry—literature and mathematics, poetry and linguistics.

There is one final consideration. The development of computing devices will in the years ahead serve to amplify enormously man's capacity for analysis; indeed, such devices are amplifiers for analytic thinking. This raises two related questions. The first has to do with the impact of technology on man's thinking. Cultural history indicates that man's ways of thinking are conditioned by the tools that he has at his disposal, for the tools become incorporated into his very thought process. They are the "print-out" to which he is geared. Yet paradoxically enough, it may well be that computers, in addition to expanding the power of analytic thinking, will also pose a need for greater and greater intuitive power. For the issue of how to use computing devices—their range and form of applicability—will itself pose a problem that can only be approached at first by intuitive means. In an age when man has developed machinery to run off the routine analytic tasks, it may well be that his best alternative is to develop inventive powers for dealing with the ill-formed and partly formed problems that remain. It is precisely in this domain that a vigorous and courageous intuitive gift, refined through practice, can serve man best.

THE DEVELOPMENT OF INTUITION

Alfred Baldwin

We have seen some of the array of cognitive skills that contribute to the acquisition of information and the understanding of new relationships, their use in the solution of problems and their functions in the process of creation. In particular the intuitive processes have been examined because of their importance for achieving understanding and creativity and also because intuition is a foundation on which the processes of analysis and formal explanation may rest.

The task of this section is to examine the developmental course of some of these skills—particularly in early childhood—and to search for educational procedures that foster that development. In any picture of cognitive development in early childhood, intuition looms large. It can be said that in some sense all of the 2-year-old's understanding of his environment is intuitive. It is global, synthetic, pictorial, and unverbalized. In what sense then must intuition be trained and fostered?

The answer to this question lies in the difference between intuition in early childhood and adulthood. While the adult's intuition retains some of its childlike character, it is not childish thinking. For effective intellecutal functioning the child's intuitive understanding must be fostered yet shaped, retained yet outgrown, and in the acquisition of unfamiliar areas of formalized knowledge it may need to be taught explicitly side by side with the formal explanations of science and mathematics.

The reconciliation of all these paradoxes lies in the fact that intuition is not a well-defined term with clear denotative meaning. Instead it is a vague term that is itself only understood intuitively. In the previous section the several aspects of intuition have been described. First it is the making of good guesses in situations where one has neither an answer nor an algorithm for obtaining it. It is frequently difficult to defend an intuitive solution although in many cases the solution can be demonstrated to be sound. The process of intuiting is difficult to describe. In fact the difficulty in giving a verbal description of intuition is one of its most characteristic hallmarks. A second aspect of intuition is therefore its unverbalizability.

Not only are hunches and intuitive solutions difficult to put into words, but those quasi-perceptual judgments of social atmosphere, personality traits, medical diagnoses, and the like are also unverbalizable.

A third feature of much intuition is its pictorial quality. Geometry is more readily intuited than algebra; phenomenally one's intuition frequently has vague pictorial or ikonic representations. Piaget uses the term *intuitive* in precisely this sense. The child at the intuitive stage can picture in his mind the event he is trying to predict and in his imagination trace it through to its outcome.

The aspects of intuition that have been analyzed out of the general term are then (1) formation of hunches in uncertain situations, (2) unverbalizable beliefs and understanding, (3) ikonic cognitive representations of environmental phenomena. We propose to examine each of these as it appears in the thinking and the behavior of young children, to assess its assets and liabilities for effective intellectual function, and to suggest educational procedures that will make it more effective. In each of these areas research opportunities abound because so much of the empirical data on which sound educational policy should be founded is missing.

Formation of Hunches

Someone has said that an intuition is a disciplined guess, and that expression conveys both the freedom and the constraint that must be balanced in creative thinking. In the thinking of young children it is probably the absence of restraint that is most conspicuous. Children constantly amaze their elders by their free and unconventional use of materials, and artists note with great joy their unconventional uses of color and shape.

The question whether children's productions are creative in the same sense as the adult artist's is debatable, but more important it is amenable to research. Young children are stimulus-oriented and uninhibited, and with stimulus support they can often produce a constant stream of unrestrained ideas. Lack of planning and anticipation are also evident; in the child's stream of ideas his creative productions often acquire names and meanings after they are complete.

This is not to say that the divergent thinking of the young child is useless. It is the first sign of a process that later will be very valuable. The preservation of the spontaneity of the young child is an important educational objective; it is all too frequently restricted and stunted by the imposition of rigid conventions and constraints. But a more obvious and pressing need during the preschool years is teaching of restraint, the withholding of judgment, and the control of impulsivity.

The situation is probably different for the older child. A decrease in spontaneity and creativity with school entrance has often been commented on. Whether the present school system is responsible is questionable. It may well be partially a result of developmental processes.

Observation of preschool children suggests that the divergent thinking of the young child depends upon external stimulation. The young child has difficulty in calling forth ideas voluntarily from within himself, as on spontaneously naming words, an intelligence test item in which the child is prevented from using environmental objects as an aid to his creative thinking. The imposition of his own volition upon his own thoughts and acts is not easy for the child. This hypothesis needs testing.

When intuitive guessing is effective, many of the ideas are constructed from within. They are deliberate modifications of previous hunches, shaped to the demands of the problem. Only when the flow of ideas dries up is it necessary to cast about for ideas or to depend on environmental suggestion.

To teach internal control over productivity to the young child, one can picture a variety of games to provide training in "remote associates" based on current tests of creative thinking. One useful variant might be to think of words that avoid some specified topic. Whether such training in remote associates would reduce dependence upon stimulus situations is an empirical question.

Turning now to procedures for training children to restrain ideas and withhold judgment, it may be fruitful to concentrate on the identification of situations that do not contain sufficient information for an answer. One of the difficult answers for a child to acquire is "I can't tell." One of the characteristics of children in experimental situations is the difficulty they have in not giving an answer—even if they have no information. If withholding answers is one desirable skill to teach, sticking to an answer is another. In experimental studies children may change their answer to every new question. The practice, related to alternation tendencies in the youngest children, only later takes on the quality of "I must have been wrong last time."

With respect to intuition, therefore, it is the hypothesis of this section that at the preschool level it is the discipline rather than the guessing that needs encouragement. At older ages—perhaps upper elementary school—the problem may be reversed.

Unverbalizable Beliefs and Judgments

A second aspect of intuitive thinking is its unverbalizability. This feature of intuition needs careful examination when we consider the problems of thinking in young children. Three reasons for the inability of the child to verbalize a belief suggest themselves:

1. Lack of awareness of the mediating process
2. Lack of coding ability
3. Vague and global ideas that are not codifiable

Probably all three contribute to the inarticulateness of young children about their own thinking processes.

Whatever virtue there is in intuitive thinking, it is not the fact that it is inarticulate. We obviously do not want deliberately to train children to be nonverbal about their beliefs. In fact, one might well argue the opposite side of the question that children need all the training they can receive in becoming effective describers of their own ideas and their reasons for holding them. Roger Brown is working on a curriculum for this purpose.

Is there a real issue here? Insofar as the inarticulateness of children is due to lack of coding ability, the answer is clear. Training in coding and decoding is all to the good.

A question arises, however, as to whether there are behavior mechanisms or cognitive processes that cannot be coded—or at least not coded into language. If that is true, then the demand that they be verablly expressed is at best unrealizable. Even worse, the verbal description of unverbalizable material is misleading. To illustrate, a bright untutored child given the problem that Tom who had 10¢, gave Dick 3¢, answered that Tom had 7¢ left. He gave the correct answer, but when asked how he got it replied that 5 and 2 make 7. This sort of verbal detour that arrives at the answer but has no relation to the process can be more misleading when it becomes subtler.

There is also a possibility that the serious attempt to put into words an intuitive belief will partially succeed but will omit something that is of real value in the thinking process. If it substituted a poor algorithm for an essentially accurate intuition, it is no gain.

Intensive coding training may encourage the individual to believe that all judgments must be verbalizable to be worth their salt. The person who refuses to use his intuition unless he can verbalize it is cutting himself off from one of his own abilities. It is this danger that perhaps underlies the demand for training intuition. The diagnostician who, because he has never acquired the intuitive skill must depend upon a poor algorithm for his diagnosis, is in a poor way. This does not mean, however, that he would not be better off if he found an algorithm that actually did reproduce his intuitive diagnostic process. The question about the realtive advantages of an algorithm or an intuition—assuming that they are equally effective—probably varies from one field to another, and with the importance of speed, of communication to others, and the extent to which the algorithm corresponds with the intuitive process rather than substituting some alternative process.

Assuming that there are unverbalizable beliefs and cognitive processes, what training methods are available for instilling them? Common sense suggests that such processes are acquired by experience in performing them. The training of motor skills can be accomplished without the individual becoming aware of the details of his actions or of the way that they are modified to meet the circumstances of concrete situations. Discriminations like those in sexing chickens can be taught in the same fashion. Practice teaching, supervised case work, supervised psychotherapy all contain large elements of nonverbal instruction. Such kinds of learning may be best described by the simplest sort of conditioning. Thus, immediacy of feedback and of reinforcement, and the avoidance of delay between the presentation of the situation and the response, may be particularly important for teaching unverbalizable skills, whereas the use of verbal methods of instruction along with feedback of information may make some of these questions of timing less critical.

One advantage of such nonverbal training is that it can be begun earlier in the child's life. The infant can learn only nonverbalizable processes. The younger the child, the more likely it is he will be unable to verbalize what he acquires from any standard training procedure. Verbalization is hard for the young child. Presumably, nonverbal instruction takes longer and is less efficient than more verbal instructional methods, but demands less maturity. Thus we can think of many kinds of infant toys, crib Skinner boxes, etc., that might be designed to teach nonverbal cognitive processes like form discrimination, perhaps left-to-right scanning, perhaps discrimination of differences in orientation. Such toys would resemble the usual cradle gyms with the exception that the feedback would be made much more obtrusive and might be put under the control of the parent to permit programed instruction.

Assuming that the basic mechanism for nonverbal learning is the repeated experiencing of contingencies—without verbal instruction or explanation or pointing—it is possible to establish such nonverbal learning at any age provided that the stimulus situation is not too easily analyzed and described, and provided that the reinforcement is blind, i.e., unexplained. Would it be valuable to introduce new subject matter is such a way in order to establish some set of intuitive or nonverbal judgments in advance of instructing in the more formal verbal rules? To some degree the strategy of beginning with concrete instances and collecting a set of those as a basis for later discussion perhaps has that function.

The decision to teach verbally or blindly turns largely upon the advantages and disadvantages of instilling in the student both a formal verbal and an intuitive nonverbal learning. The decision may well be different for different disciplines and must depend on research in each case. Some hypotheses and suggestions may, however, be in order.

One case in which the independent teaching of both intuitive skills and verbal algorithms may be especially valuable is where there is good reason to believe that the algorithm and the intuitive judgment depend on different cues. For example, the intuitive diagnosis of disease in some cases depends upon completely different cues from the definitive diagnostic test. Estimation in mathematics may depend upon processes that are quite different from the algorithms, or in other cases are merely incomplete carrying out of the algorithms. Another problem is the strategy of verbalizing or formalizing a process that is already mastered intuitively (see Bruner).

The nonverbal process discussed thus far represents pure cases, represented in the limit by perception where (1) the process of depth perception is directly experienced without verbal mediation, and (2) is essentially veridical. Another set of problems arises when we consider the kind of cognitive process described by Piaget for the pre-operational child who fails to show conservation of number or quantity. Here the child's judgment is faulty in terms of the conventional right answer, and it is not entirely non-verbal either. Yet there does seem to be some verbal difficulty that is part of his problem. Should we view the child as lacking in coding ability?

We can reject the hypothesis that the child's trouble lies in his coding ability in one extreme meaning of the term. The child who reports that two arrays of objects containing the same number do not contain the same number when one of the rows is spread out, does not merely lack the word for "same" as an adult might who was trying to answer the question in a foreign language.

On the other hand, the child does seem to show inconsistencies in coding different situations as "more" or not. Thus a child may recognize that there are more objects when one is added, or recognize that there are more if one array is denser but the same length, or is longer but equally dense. Thus he uses the word *more* in appropriate ways but also uses it to describe the situation when the objects are spread out and less dense. *More* does not mean *longer; more* does not mean *denser*. There is no single word in English that codes all the situations to which the child says "more." The research question is whether the child has a concept or set of concepts that governs his responses or whether he is merely displaying inconsistency. In a theory of childhood thought is there a lawfulness that is as yet undiscovered, or is it merely the inconsistency of the child's psychological functioning with its dependencies on irrelevant stimulus factors?

Ikonic Representations

The third aspect of the term intuition is its pictorial or ikonic quality. There is a sense in which ikonic representation is related to nonverbal. "A picture is worth a thousand words" expresses the fact that pictorial representations are not easily coded into words.

Part of the problem seems to be that the picture is instantaneous, so to speak. All the elements of it are apprehended more or less stimultaneously. The verbal description, on the other hand, is sequential. There are very real constraints on what can be pictorially represented, but there are equally real advantages to a pictorial representation.

This time-binding function is to be emphasized because there is a similar relation between a pictorial representation and the behavior with respect to it. Overt behavior is also largely sequential; the person does one act after another.

On the input side, a cognitive representation may picture the relation between events in a sequence, and this time-binding is an important feature of cognitive processes. As Piaget has pointed out, the failure of the child to understand and utilize his past experience for judging the present situation is one important aspect of his failure in conservation problems and in other types of adaptive behavior as well.

The achievement of a cognitive representation that permits temporally distinct events to be contrasted and compared and used as if they were simultaneously present is thus an important achievement.

The child can use abundant training in time-binding, and it seems reasonable that such instruction would facilitate intellectual functioning. The age at which this sort of training is perhaps most required is during the preschool period.

Some of the sorts of experiences that might contribute to the child's ability to integrate temporally discrete experiences are those which represent temporal change or temporal comparisons in a single representation, or those which make perceptual the features of a situation that remains invariant under temporal change. Experiences with reversibility that emphasize the possibility of reestablishing a previously existing situation may also be important. The mere repetition of a previous state helps to separate the description of a situation from its temporal location. Time does not stop and it is irreversible; yet situations can exist and reexist within this irreversible stream.

One way to provide the child with visual markers of temporal change is to institute play with before and after pictures. The experience of putting pictures into temporal order may be useful, particularly if the child pays attention to the continuity of the changes that take place as well as the constancies. Sandbox play could be used by placing markers in the sand to represent the successive positions of a toy car. Here the child is making a representation that has a maximum correspondence with the events that it maps. From this, other forms of representation could be developed.

There are many changes of objects or arrangements that leave some readily perceptible feature constant; for example, one object of a set may not move. The identification of this sort of invariance and the explicit recognition that some things do not change under transformations, may make it easier for the child to discover the invariance of less perceivable features of the situation like "number of objects." One kind of invariance that could also be investigated by the child is functional invariance. What can be done to a block of wood does not change its usefulness in being part of the foundation of a house. After all, most of the invariant properties of objects under transformations are closely related to some functional use of the object.

In considering these sorts of experiences as educational procedures, one is struck by the fact that many of them are available as toys all the time and form part of the free play of children both at home and at preschool. The usefulness of such experiences for conveying the idea of invariance and representation depends upon their controlled use.

In much current practice in preschool the twin notions of "free play" and "acceptance of the child" prevent the full value of play experiences for cognitive development from being realized. Unit blocks, for example, are commonplace in nursery schools and homes, and the child even utilizes the equivalent of units to some degree. But the fact that most block-building is not sufficiently goal-directed to pose problems that the child must think about to solve keeps him from discovering explicitly some of the different sets of blocks that may be functional equivalents. Perhaps some blocks should be kept reserved for more controlled games, or better yet, blocks might be devised with limited degrees of freedom and with intrinsic built-in goals. Jigsaw puzzles are good examples of this species of toy, and they are useful. Jigsaw puzzles composed of geometrical shapes, where the construction reveals the geometrical properties and the invariances between different arrangements of blocks, would seem useful additions.

Within organized preschool situations the teacher can provide some of the structure and restraints for the maximal educational use of some of the play equipment. There are also ways by which she could exercise more control than is currently popular in demanding realistic statements and beliefs. It seems likely that most of the controls on preschool children are exercised with respect to routines, i.e., fixed sequences of activities where the emphasis is on the sequence and reproducing it, rather than upon attaining a fixed outcome but letting the means vary.

This is not to depreciate the value of genuine free play and the general wisdom of accepting the child for what he is. It is only to suggest that there are some situations which can be used deliberately for the enhancement of cognitive development and the development of problem-solving and realistic appreciation of the properties of the real world.

TUTOR AND LEARNER

Rose Olver

> "The relation between the one who instructs and the one who is instructed is never indifferent in its effect upon learning."
> (Bruner, *Theorems*)

The relation between tutor and learner involves more than a one-way transmission of knowledge from a person who knows to one who does not. The tutor is a communicator of information, but he is also a model of intellectual functioning—for daring, excitement, etc. and a potential identification figure. Although this discussion will focus on the contingent link between tutor and learner in communication, the other functions of the tutor in the instructional situation must be kept in mind, for they may disrupt or facilitate the communication process. For example, communication of information from female teacher to young male student may be reduced by the tutor's unsuitableness as an identification figure; or communication between tutor and learner may be enhanced if the tutor is an older child more easily identified with than a remote "model of greatness."

That the communication of knowledge involves an interaction between tutor and learner, and proceeds most effectively when this interaction is immediate rather than remote, is vividly illustrated by the comparison of mathematics learning films of the instructor in the classroom with textbooks produced by the same projects. The chief difference seems to be that the live instructor is responsive and sensitive to the individual learner, while the text is fixed, constrained, and considerably less exciting in presentation. One mathematician remarked that his best classes were the ones where he did not enter the classroom with a fixed presentation in mind. It seems then that an optimal relation between tutor and learner permits the learner to participate in the selection and sequencing of material.

Since the contingent relation of tutor and learner has been most clearly expressed in the learning of language, let us briefly examine some aspects of how this interaction proceeds, with the hope of extending the principles to a more general consideration of the tutor-learner relationship. Consider first the reduction-expansion cycle in the sentence game that "takes children from what they know to a little more than they know rather that from total ignorance to full knowledge" (Brown, *From Codability to Coding Ability*). This cycle is characterized by the expansion by the tutor of a statement made by the learner—this expansion being the sentence that the tutor judges the learner to have meant. The learner reduces the tutor's sentence; the tutor expands the learner's. Three points of general relevance to the tutor-learner situation should be noted:

1. The expansion-reduction-expansion cycle involves reciprocal transformations. What the tutor says depends on what the child says, and what the child says depends on the tutor's statements.
2. The tutor's expansion is more complete than the child's and thus "leads" the child's knowledge; however, this leading gap is not overly large and its size depends on mutual comprehension between tutor and learner.
3. The reduction-expansion cycle provides for two possibilities of checking for understanding and comprehension—by action consequences and by a kind of back translation in situational context.

The reduction-expansion cycle is followed by a sequence of statement-by-child—extension-by-adult in which the tutor's utterance is predicated upon an interpretation of what the child said rather than being an expansion of the child's statement. Thus the gap between the tutor's statement and that of the learner is increased. However, the interdependence of tutor and learner statements is maintained and the comprehension check, though more difficult, can still be carried out through action implications or judgments of whether the sentence that is given in response could have been "inspired" by correct understanding.

In summary, the contingent relation between tutor and learner implies that the tutor start where the learner is—in terms of what he knows and what skills and abilities he has—lead the learner by expansion and extension of what he produces, permit the learner to participate in deciding what aspect of the topic is to be considered, and provide ample encouragement and opportunity for signaling of incomprehension on the side of both the tutor and the learner.

Since the relation of tutor and learner is a relation between one who possesses some knowledge and one who does not, there is an authority relation involved in the instructional situation. How such a relation is handled affects the nature of the learning that occurs and the degree to which the learner will pursue learning activities on his own. Studies of authoritarian and democratic play groups are suggestive in this context, for there is evidence that, although authoritarianly directed children "get more done," they work only when the leader is present and quickly drop the task when he is absent. In contrast, under democratic leadership, where the children have the opportunity to participate in group decisions both about goals and about how to get to them, activity is continued in the absence of the leader. We should not, however, jump to the conclusion that children are not willing to work under direction. There is the story of the child in an extremely permissive class who pleadingly asked, "Teacher, do I *have* to do what I want to today?" It is rather a matter of balance of power and control than of authority versus no authority.

In the instructional situation the tutor is often initially in control of both the terminal states that may follow upon an attempt to know something or master some task: success or failure, and reward or punishment. Although success or failure has to do with whether or not the learner has reached some criterion state inherent in, rather than external to, the task at hand, it seems likely that there are many instructional situations in which successful solutions or mastery are not immediately obvious to the learner. That is, until the criteria for judging success are available to the learner, he must depend on the tutor to indicate when success has been achieved. For example, the successful mastery of learning to ride a bicycle is more easily judged by the learner than the successful mastery of learning to write a book report, since it has direct behavioral consequences as criteria. In order for the child to proceed on his own he must come to recognize success when it occurs; that is, he must learn the internal-to-the-task checks by which success or failure may be identified.

Whether or not successful mastery of a task is inherently rewarding to the learner, it seems likely that learners require some payoff for intellectual work beyond that of using their minds to master problems, particularly if the activity must be continued for some length of time. Indeed some initial external rewards may be necessary to tempt the learner into a situation in which he can discover that tackling problems can be intrinsically rewarding, as well as to guide him through initial stages of learning until success can be encountered. There is a connection between success in intellectual activity and reward that must be established in the tutor-learner relation. This connection is often built by using reward to indicate to the learner that he has been successful and punishment to indicate that he has failed.

There are, however, a great many dangers in allowing dependence on external reward: intellectual activity may cease when such rewards are not present; information is acquired in a form that has limited flexibility and utility for correction, etc. (A detailed discussion of learning under extrinsic reward and punishment can be found in Bruner's *Theorems* working paper.) Thus it is necessary to transfer the rewarding function from external sources, such as the tutor, to the task and the learner. How may this be accomplished?

In order for this transition to be accomplished, the functions served by external reward must be transferred to the control of the learner. For example, external reward may be the criterion by which success and failure are judged in the absence of task-relevant criteria. Thus in order to give up reliance on external reward the learner must receive feedback from the *task* of how he is doing. For this to occur, the learner's encounter with materials to be learned or problems to be solved must provide opportunity for feedback. Such an arrangement of materials will include presentation of their structure, so that the learner can utilize negative, as well as positive, information.

Much has been said at this conference about the importance of maximizing the informativeness of error or failure. The informativeness of success should be maximized as well. Successful completion of a problem can be as uninformative as the failure to solve it—save that success indicates that the problem can be solved—if the learner is not aware of the process by which success was achieved. As it is often necessary to repeat a sequence of activity that led to failure to see where one went wrong, it may also be necessary to repeat a sequence of activity that led to success to see where one went right—unless, of course, some record, internal or external, was kept. The tutor may keep the record for the learner; but if the learner is to be able to proceed on his own, he must be taught to keep records for himself.

Transfer of reward from the tutor to the task may be aided by the relating of the extrinsic reward (by the tutor) to the task itself. For example, rather than praising the child for success, praise his successful use of a skill. This implies that external rewards should be placed in the learning situation only after some meaningful segment of activity has been accomplished so that its relation to the task can be seen. The tutor thus by his placing and phrasing of external rewards can facilitate their transition to internal rewards.

Since too little external reward leads to a reduction in effort, and too much produces difficulties by disrupting or stereotyping learning, an optimum balance between external and internal rewards must be established. This optimum balance will in part be determined by the child's level of development—for example, his capacity to delay gratification. It will depend upon his ability to span a sequence of events and consider them as a larger unit such that external reward may apply to the initiation and continuation of activity as well as to the termination of an endeavor. Some attention then must be paid to the assistance of the development of cognitive organization—that is, the forms of representation that allow the child to deal with sequences of events in a more simultaneous fashion such as ikonic and symbolic representations. In addition it may be possible to supply the child with external devices for assisting his structuring of material, written notations, and so forth.

If external reward serves to encourage the child to continue intellectual activity for other than task success, may it not be that external rewards can be profitably introduced to encourage the child to continue when the task is not going well? Not, of course, to reinforce failure, but to support the child's learning of techniques for overcoming failure. Would the child, if given free access to some external reward—candy or the like—reward himself for successes in his task or turn to external reward when the going gets rough and the task is not providing success?

This raises the question of whether or not the tutor should allow the child to fail. When learning on his own without the tutor present, the child is bound to fail occasionally. If he never experiences failure in the supportive atmosphere of the tutor-learner situation, he will not learn techniques for rendering failure informative or for avoiding it. Without prior experience of failure in the tutor-learner situation the child's first experience of failure on his own in intellectual tasks may prove overwhelming and lead him to abandon his independent learning activity.

When they play guessing games, children often use a technique for giving continuous feedback to the player about how he is doing. They tell him that he is "getting warmer" or "getting colder" as he works his way through the problem. The warmer-colder feedback does not have the finality of a "You're right" or "wrong" response, and thus serves to keep activity going and in the correct direction. Of course in the guessing games the warmer-colder must be supplied by the other player but it does have the property of being related to the task, providing for correction, and avoiding persistence on the wrong track. Perhaps the goal of the tutor-learner relation is to give to the *task* the function of saying warmer and colder by presenting materials in a structured fashion that allows the child not only to see the gap between where he is and where he wants to be, but also how he's progressing as he works between goals and subgoals. This may be a major distinction between external and internal reward: that external reward is more applicable to some end point, while internal reward can support process as well as product.

In the typical classroom, the teacher is unable to respond to children singly as individuals; instead, responses are doled out to the group as a whole. In such a situation, the child may turn to internal rewards since, in a sense, the tutor is not there to reward him at appropriate moments.

THE STRATEGY OF INSTRUCTION

William Kessen

From Schema to Sequence

Each school subject—whether in the humanities, in the sciences, or in mathematics—has its traditional structure. Some of the new curriculums have shaken the old patterns but, old or new, a school subject—because it is necessarily the product of agreement among adults—has an accepted schematic form. The range of variation among subject schemata is great, to be sure, from the elegant linearity of some mathematical study to the looser structures of language, arts, and social studies. It is an elemental task of the educator to transform the structure of a discipline—the integrated conceptual schema that represents some part of man's knowledge—to a sequence of events that is comprehensible to the learning child.

The problem of transformation from schema to sequence does not admit of unique solution; numberless possible arrangements of a discipline can be imagined and much current dispute about children's learning in school turns about the related issues of unit size and sequencing. The paragraphs that follow are organized around only one theme in the transmutation of a field of study into a temporal organization of teaching materials. It will be maintained that, within the diversity of solutions that have been attempted on this problem, there has been a remarkable congruence in principle and, further, that the principle itself is wrong-headed.

The Image of the Vector

A look into the textbooks of the school child will reveal the basic principle of subject organization: that the child be moved monotonically and step by step through material of increasing complexity. This form of the principle has the neat economy of exaggeration; very nearly every word in it could be used for an educational epistle. Nonetheless, the exaggeration is restrained. The analytic manner so dominates the builders of curriculums and the writers of textbooks that the child is almost inevitably exposed to a hyperrefined reading of the discipline, one in which all the messy, uneven, and wonderful irregularity has been carefully ground down. The resulting construction often has elegance and logical simplicity, and it often makes what adults call good sense. But one may ask whether the image of the vector—the monotonic presentation of a cleaned-up and hypothetically essential form of a discipline—is a proper model for education.

The Uses of Uncertainty

In the workaday world of teachers and children, the clarity and elegance of a subject are rarely given straight. Only the weakest and most ignorant teacher will march her charges close-ranks to the textbook tune. In fact, one of the marks of the great teacher at all levels of educational practice may be the ability effectively to introduce variability and uncertainty to the subject under study; in a play on the language of communication theory, this addition that the skillful teacher makes can be called "happy noise." The student of such a teacher sees not a vector, but a loopy collection of lines—even, in the most daring and exciting teaching, a controlled kaleidoscope.

Several very different lines of research have been drawing attention to the potency and ubiquity of intrinsic sources of cognitive change, sources independent of tissue need and tissue injury. Work on exploratory behavior, on responses to unexpected events, on cognitive imbalance, on teaching methods that emphasize discovery, as well as Piaget's theoretical propositions about cognitive equilibration, have created a new specialty in psychology and a new promise for educational practice.

Many of the revaluations of thinking put the relation between the structure of the person and the structure of the environment in the center of theoretical consideration. The properties of external stimulation that are seen as critical with respect to intrinsic sources of change are those that are customarily covered by such words as "novelty," "change," "surprisingness," "complexity," "incongruity," "ambiguity," and "lack of clarity." Attempts to bring this variety under a single set of theoretical notions have depended chiefly on discrepancy between incoming stimulation and expected stimulation, inconsistency among inputs, and conflict among simultaneous and incompatible response tendencies. Whatever the theoretical underlay, evidence has begun to accumulate that skillful variation of environmental uncertainty can increase retention, understanding, transfer to new situations, recognition of problem solutions, when achieved, and the tendency of the child to search for information. Against this background of recent research and speculation, several problems of importance for education can be detected.

Plurality of Path

A school discipline, before it reaches the stability of a textbook or a curriculum guide, has been subjected to the analytic reduction of adult symbolization. In most cases, this reduction has met the further requirement of agreement among several experts—poets write few textbooks. It is regular, therefore, for the forms of school subjects to be far away from the images and intuitions of the men who discovered or invented the field of study. Yet when we ask the child to learn, we ask him to invent or discover the field anew. If this discovery is to be active, incorporative, and modifying, then the child must be free to construct his own form of the knowledge. The learner's form and the teacher's form must be congruent in its symbolized and public aspect, but this requirement of ultimate agreement does not demand that each step of the child's search for order be available to public statement or the same from child to child. On the contrary, the evidence of human variation should convince us that many paths may be taken to the goal of learning. Whether the child is learning about factoring or pendulums, about the place of legislatures or the motivations of Brutus, he should be given every reasonable chance to build his own links from problem to solution. The great teacher leaves the canonical expression of her material to suggest alternative approaches, to provoke independent analysis, and to free the child from his wish for effortless clarity. It is not necessary for the child to repeat each step of Thales and Lavoisier; it is necessary for him to participate in the acquisition of knowledge. The task of the teacher—the task that makes education the most demanding of professions—is to set the occasions for the child's active development of knowledge.

There are several practical and difficult problems that arise from an advocacy of the use of uncertainty as a device to insure plurality of learning. Probably the most important is the need for competence in the teacher. Although it is boring to be but a mobile and vocal extension of the teacher's manual, it is not intellectually demanding. To be so much more than this that the child is moved to directed exploration requires a full command of the subject matter by the teacher. Science education in the first years of school has long been retarded by the inadequate preparation of teachers in science and their consequent fear of science. If the teacher is afraid that an inventive child will ask a question or start in a direction that she cannot answer or control, there is little hope that teaching for plurality will succeed. More than that, the picture of the textbook as an island of safety will be taught by the poorly trained teacher willy-nilly to her students. The teacher must recognize the unusual solution, the going-astray that may find a great deal more than the problem required, and the confusion of students that demands intervention and new direction. In the light of present educational practice, particularly in the elementary school, this may seem an inhuman demand on teachers; the skills may be cheaply bought, however, by changes in the training of teachers to make their education in college more like the exploratory and discovering strategy that has been advocated for their students.

This last point is relevant to another characteristic of the teacher of plurality. There will be occasions when no answer can be given, when the child (and the teacher) must be left with the problem unsolved or the assigned task uncompleted. Not only will there be such ambiguity and delay from problem to problem; there will doubtless be wide variation in the tactics of solution used by different children. Not easy circumstances for the orderly adults that so many of our teachers are! A tolerance for delay, a willingness to accept ambiguity at least for a while, and a respect for variation among children are essential virtues for the teacher of plural paths.

No specific assumptions have been made here about how long or over how wide a range of material a problem should remain open for the child. Within a subject within a grade, the problem-unit—*that is, the span of study which ends with a demand that the child* match his construction with the model of public agreement—may be quite small. Exploration of the balance beam in third grade may, for example, go on for only a session or two before the child is asked to produce a communicable argument. On the other hand, some problem-units may reasonably extend over several years. This broadening of the range of active learning clearly has implication for changes in typical school organization, but some of the larger themes of the social studies curriculum under construction by ESI, for example, seem well suited to continuation from one grade to another.

Optimal Uncertainty

The most uncertain program of study that can be imagined would involve exposing the child to a random order of randomly determined events. It is unlikely that discovery would be common under such circumstances. The use of uncertainty in teaching is determined jointly by the cognitive structure—the cognitive position—of the child and by the amount of uncertainty in the environment. To the child who knows how to read, it is uninteresting to practice saying the alphabet (low uncertainty); to the child who does not know the alphabet, it is uninteresting to be given a page of written text (high uncertainty). As Piaget has suggested, cognitive change takes place in the relatively narrow range of moderate uncertainty. Those events which are easily assimilated to an existing schema do not lead to change; those events which are beyond the reach of accommodation do not lead to change; only in the band where accommodation both must and can take place will cognitive change result. The child can learn only in the range of the knowable unknown. This general proposition about the optimal conditions for intellectual change brings in its train some interesting suggestions about the education of children.

Boredom and Disruption.—As every teacher and many parents know, the "understimulated" child is bored and the "overstimulated" child is under stress. It may extend our understanding of these conditions to recognize that the child who finds too little uncertainty in his schoolwork will move to increase it and the child who finds too much uncertainty in his schoolwork will move to reduce it. In the first case, the search for optimal uncertainty may lead the child to new investigations of his own, reading more on a subject of interest to him, trying out his ideas in writing or laboratory work, asking the teacher for directions to new knowledge. Unhappily, the topography and sociology of the American schoolroom do not make these extensions into uncertainty simple for the child. His restriction to a desk and to a specific unit of work, the organization of the schoolday by a fixed schedule, the inability of the typical teacher to turn from her job of getting everyone up to a minimal level of competence—all of these conditions tend to direct the child in search of uncertainty toward cognitively ineffective maneuvers. The bright student who knows how to spell "July" and who is required to write "July" 15 times for spelling drill may, in search of some variation, produce a list that reads, "July, July, July, Jluy, Jyul, Yulj. . . ." Or the child who has finished the day's prescribed work and who is not permitted to go to the library table may find happy uncertainty in attempting to distract his neighbor or the teacher. Note that busy work will not do to reduce this apparent boredom; only if the child is given a task relevant to his cognitive position will he be able to think effectively. A practical implication of this analysis may entail the establishment of workrooms partially independent of the regular schoolroom where the child who has met the requirements of the day may go to follow up some part of his work that remains in the band of accommodation.

The problem of the child who is presented with more uncertainty than he can manage—who, in Piaget's terms, is beyond accommodation—is probably less common in American schools but is no less difficult to solve. Oftentimes the child makes an apparent solution which is acceptable to the teacher but which does not involve the active discovery and incorporation that underlie stable retention and transfer. A major species of mock accommodation is imitation of the teacher and the text. In this form of uncertainty reduction, it is not the domain of objects, thoughts, and symbols that is modified; it is rather a curious kind of social domain that the child measures by the satisfaction of the teacher independently of perceived changes in his understanding of the problems posed. Grosser forms of response to excessive uncertainty in school—flight, in the extreme case—remove the child completely from the opportunity for cognitive change. For these children, too, repetition of materials not yet understood may be an inappropriate tactic. Variation in the specific form of instructional material with only slight changes in conceptual uncertainty offers a more likely procedure for optimizing uncertainty for the child in school stress.

Variation Among Children.—The range that is represented at its extremes by the bored and by the stressed child is wide and almost certainly not unidimensional. Children will vary in their cognitive position—in the depth of their comprehension of a subject—and they will vary too in their ability to accept uncertainty. It is an unsolved problem in educational psychology to assess the child's response to changes in uncertainty.

Supports to Optimal Uncertainty: Teachers, Teaching Machines, and Textbooks.—The presence of great variation in both competence and response to uncertainty makes the teaching task one that demands sensitive flexibility. The obvious advantage of teaching machines is that the program can be made to fit the child and the child can proceed at his own (by assumption, uncertainty-relevant) pace. The disadvantage of such an aid that is clear in the present context is the inability of the programed material to dose the introduction of uncertainty on the evidence of the child's comprehension.

The textbook has very little to recommend it as a device for maintaining optimal uncertainty. Because it is typically written as an idealized form of a discipline, because it is necessarily written in a single form and therefore cannot be sensitive to variation among students, because the relation of the student to it is always in some degree passive, the textbook will always be ancillary rather than central to the training of active search and the control of uncertainty. To the degree that the teacher models her behavior on the shape of the textbook, to that degree the book may have a negative and encumbering effect on the process of education, particularly in the early grades of school. As a place to find answers, the textbook is a sound teaching device; as a support to optimal uncertainty, it is often of little value indeed.

The human teacher, aware of each child's competence and possessing some understanding of each child's ability to accept and use uncertainty, remains the most flexible and sensitive teaching device available. Barring unseen advances in technology, only the teacher can move fast enough to modify uncertainty effectively, vary her management of the environment to assure some useful uncertainty for most students, and support the development of many paths to the solution of problems. This is not, however, the teacher in today's schools; she is a teacher freed of routine and mindless tasks, well enough trained to be secure in her understanding of the subject she teaches, and with classes of a size small enough to permit her to be sensitive to the variation of children.

NOTES ON INTRINSIC MOTIVATION AND INTRINSIC REWARD IN RELATION TO INSTRUCTION

Daniel E. Berlyne

Introduction

Several very different lines of research have been drawing attention to the potency and ubiquity of "intrinsic" sources of motivation and reward. The term "intrinsic" refers to factors that are relatively independent of tissue needs involving systems other than the sensory and nervous systems (e.g., hunger) and of external agents with specific beneficent or noxious effects (e.g., pain). Instead, these factors hinge on harmonious or disharmonious relations among processes ("responses" in the widest sense of this word) going on simultaneously within the organism. These relations are determined largely by "structural" and "attention-commanding" properties of external and symbolic internal stimulus patterns, including some that are considered biologically neutral or indifferent.

Among the main currents of research that have contributed to the recognition of intrinsic motivational factors are:

1. Work derived from an interest in exploratory behavior and more lately concentrating on the more general motivational and psycho-physiological significance of the main stimulus properties that govern exploratory behavior.

2. The writings of men like Hebb and McClelland in the United States, and Anokhin in the U.S.S.R., concerning the hedonic and disturbing effects of stimuli that depart from what the organism is expecting or is set to receive.

3. Theories singling out "incongruity," "dissonance," and "cognitive imbalance" as states that may result from inconsistencies among attitudes and may consequently promote attitude change.

4. The ideas of Piaget regarding "equilibration," "assimilation" and "accommodation," supported by the recent experiments of Smedslund.

5. Experimental work on latent and incidental learning, which

has somewhat died down in the West but is quite actively carried on in the U.S.S.R.

6. The apparent success of teaching methods encouraging active search and discovery both in the United States and in the U.S.S.R. (cf. the volume of the *Izvestiia* of the Academy of Pedagogical Sciences devoted to children's "interests" in 1955).

More detailed expositions of what is meant by intrinsic motivation and reward, of pertinent theoretical problems, and of experimental results bearing on them are to be found in references 1, 2, 3, and 4 at the end of this article. A treatment with special reference to thinking is in preparation (3).

Theoretical Interpretations

The properties of external stimulus patterns that seem to be of greatest moment with respect to intrinsic motivational states are those that are customarily covered by such words as "novelty," "change," "surprisingness," "complexity," "incongruity," "ambiguity," "lack of clarity," etc. These terms apply to a number of concepts that are logically distinguishable but often correlated in practice. I have proposed the term "collative" to refer to them all collectively, since they depend on collation of information from different sources, whether they be different sectors of the present stimulus field or stimulus elements belonging to the present stimulus field and to the organism's past experience. There have been a number of attempts to capture theoretically what these properties have in common to give them the effects that they apparently share. Different writers have stressed *discrepancy* between inputs, and *conflict* among simultaneously instigated but incompatible response tendencies. My own reasons for preferring the hypothesis that conflict is the operative factor are given elsewhere (2).

With regard to the intrinsic motivational states that actuate and direct "epistemic" behavior, i.e., knowledge-seeking behavior which includes consultation, observation, and directed thinking, *conceptual conflict*, i.e., conflict among incompatible symbolic response-tendencies (beliefs, thoughts, attitudes, etc.) is presumably involved. Important special cases of conceptual conflict are (1) perplexity, (2) *doubt*, (3) contradiction, (4) conceptual incongruity, and (5) irrelevance. It is assumed that, whenever a subject is completely blocked or "stumped," i.e., completely at a loss for an answer to a question, some thoughts, if only irrelevant ones, will actually occur. The stream of thought will therefore be led off equally powerfully in several divergent directions at once, leading to conceptual conflict of one or more kinds. The notion of conflict is related to the information-theoretic notion of "uncertainty." Novel, surprising, or puzzling situations are assumed to engender subjective uncertainty (a concept that bears the same relation to information-theoretic uncertainty as subjective probability bears to objective probability) and hence conflict. Information accruing through exploratory or epistemic behavior is assumed to reduce conflict and subjective uncertainty and, by relieving the aversive state that coincides with them, to have rewarding or reinforcing effects.

Pedagogical Applications

Various considerations, some of them stemming from basic theoretical points, some from experimental work, and some from universal educational experience, suggest strongly that intrinsic motivational states and rewards can, if skillfully utilized, enormously increase (1) retention of new material, (2) understanding of new material (judged by capacity for fruitful transfer to new situations, reformulation in pupils' own words, etc.), (3) active search for information, (4) ability to solve problems by directed thinking, (5) recognition of a solution to a problem once attained. At any rate, further research on how far these variables are actually affected should surely have a high priority.

The actual manner in which intrinsic motivational factors can be exploited will obviously vary with the subject matter. Their deft and judicious manipulation appears to be part of the stock-in-trade of any skillful teacher or writer. Most of the devices used to stimulate "curiosity," "interest" or "attention" will, upon examination, turn out to depend on proper management of the factors subsumed under "conceptual conflict," and "conceptual-conflict reduction."

Some of the special cases that spring to mind are:

(1) Use of *surprisingness*, for example, in natural-science lessons, by presenting phenomena that contradict expectations based on prior learning. This is followed by the rewarding experience of adaptation to surprise, as the reality of the surprising phenomena is registered and expectations are accordingly reorganized.

(2) The stimulation of *doubt*, e.g., by presenting a general principle that may or may not be valid (cf. some of D. Page's techniques). Doubt is relieved as the accumulation of instances convinces the pupil of the validity of the principle, and this is perhaps completed by something equivalent to a proof.

(3) The production of *uncertainty* by setting a problem that may have a number of different answers (cf. the Harvard geography lesson in which pupils have to guess the locations of cities on a map showing only natural features of the territory). Uncertainty is

subsequently relieved, as one of the competing possibilities is selected as an answer and its validity is checked.

(4) Confrontation with *difficulty*, which usually means conflict due to apparently irreconcilable demands of a situation. This can be achieved by presenting pupils with a practical task, by identification with a fictitious character who is faced with the problem, or, in older students, by simple abstract presentation of the problem (cf. the studies of Morozova in Russia, presenting the problem of finding geographical co-ordinates in the middle of the desert). The difficulty is eventually resolved, whether by the student's own efforts or by help from the teacher after the student has attempted the problem, and gives way to a rewarding sense of mastery.

(5) The presentation of an apparent *contradiction*, which may include what mathematicians call "counter-intuitive propositions." The student is shown, for example, that the number of even integers is equal to the total number of integers, that the number of points in a 1-inch line segment is equal to the number of points in a 1-mile cube, or, to use an example from Morozova, he is told, after a lecture on how plants use chlorophyll to carry out photochemical reactions, that there are plants that exist without chlorophyll and without sunlight. In this way, inadequacies in existing representational structures are brought into prominence, and reorganizations to make these structures better adapted to reality are prompted.

Special Problems

The following problems stand out among those that are of obvious interest both for basic psychological theory and for educational practice and cry out for further research:

(1) In many cases of problem-solving by thinking and absorption of information supplied by instruction, as in many instances of enjoyment of humor and art, there are two sharply differentiated phases: a phase of discomfiture (high drive or high arousal), precipitated by conflict of one sort or another, is followed by a phase of relief, identifiable with conflict reduction. In other instances, the successive phases are not clearly recognizable, but there are obviously factors at work and interacting that can be characterized as discomforting (arousal-increasing) and relieving (arousal-reducing) respectively. In yet other instances, everything happens in a flash, as it were, so that these two kinds of factor cannot be distinguished: there is simply a sudden experience of enlightenment, mastery, or striking sensory impression.

It would seem likely, especially in view of psycho-physiological evidence that the striking experiences are accompanied by a fleeting rise, followed by a prompt fall, in the standard indices of arousal, that, in all these instances, there is actually a phase of discomfiture followed by a phase of relief. It would seem that, when these two phases are not recognizable, it is simply because one succeeds the other too quickly for them to be easily recognizable. If this hypothesis turns out to be true, then the pedagogical implications will be considerable, since separate techniques for stimulation of discomfiture or arousal of curiosity, and for alleviation of discomfiture or arousal of curiosity would have to be studied and developed.

(2) Conceptual conflict will, if our first hypotheses are correct, determine the degree of "epistemic curiosity," i.e., how eager a student is to find the answer to a question and how powerful the reinforcing effect of his finding an answer will be. But, as with most other behavior, the likelihood of engagement in the form of behavior and the degree of persistence without success will not depend solely on how much a subject would like to succeed. Such factors as subjective probabilities of success and costs (in time, effort, etc.) of a search for an answer must play a part. In other words, we are up against the problems that have been handled in the past by concepts such as "level of aspiration." To maximize active searches for knowledge, it is therefore necessary to dose the generation and alleviation of conflict and the subject's experiences of success and failure so as to maximize the subjective probability of success. High motivation to succeed combined with expectation of failure is likely to produce frustration and discouragement.

(3) Following on point (2), one must beware of supposing that what is desirable is maximum readiness to engage in searches for knowledge and maximum persistence in carrying out such searches. Some obsessive-compulsive symptoms can be interpreted as tendencies to excessive exploratory and epistemic behavior; the patient explores and thinks far too long before arriving at a conclusion or feeling ready to embark on an action. Furthermore, when a subject is motivated to solve a problem, the advantages of autonomous thinking must be weighed against those of alternative ways of obtaining information, such as consultation of experts or books and observation or experimentation. Lastly, we do not want students to waste time on problems that are beyond their capacities.

The ideal product of the educational system will presumably be an individual who (1) knows his own problem-solving capacities well enough to judge when it is worth his while to attempt to find the solution to a particular problem, (2) is able to work out the most effective combination of epistemic techniques, including directed thinking, for a particular problem, and (3) is prepared to accept tentative or maximally probable propositions, while recogmizing their liability to be discredited subsequently, and is able to act after a due but not excessive amount of information collection.

References

1. Berlyne, D. E., *Conflict, Arousal and Curiosity* (McGraw-Hill Book Co., Inc., New York, 1960).

2. ——— "Exploratory and Epistemic Behavior," (in Koch, S., Ed., *Psychology: A Study of a Science*, Vol. 5, McGraw-Hill Book Co., Inc., New York, 1963).

3. ——— *Structure and Direction in Thinking* (in preparation, to be published by Wiley & Co.).

4. Fiske, D. W., and Maddi, S. R., *Functions of Varied Experience* (The Dorsey Press, Inc., Homewood, Ill., 1961).

5. Hunt, J. M., "Motivation Inherent in Information Processing and Action," (in Harvey, O. J., Ed., *Cognitive Factors in Motivation and Social Organization*, Ronald Press, New York, 1963).

SCHOOL ARRANGEMENTS

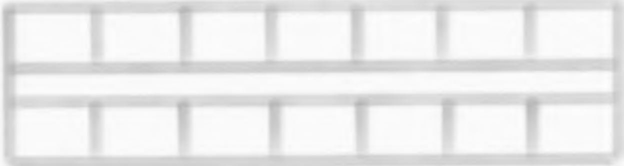
Blythe Clinchy

When we think about the problem of instruction we are likely to think both too little and too much about the context in which instruction will take place. The spatial and temporal arrangements within a school, the ways in which teachers and children are deployed—all this seems dull and shallow indeed when set beside the deep, electric questions of cognition, development, and the like. Yet arrangements put constraints on curriculums and curriculums make demands upon arrangements. The existing pattern of school arrangements, no matter how craftily you try to circumvent it, will always manage to defeat a curriculum which is inappropriate to it. The moral is clear: Do not think of instruction apart from the constraints imposed by its context.

But there is another, opposite moral, and it is this one which I recommend to those who are concerned with long-range research: When thinking about the process of instruction forget, so far as you can, what little you may know about existing school arrangements. Much can be lost by pouring our new wines into these old bottles. The existing school patterns are a part of our culture and, as such, insinuate themselves into our thinking about questions of instruction so that, for instance, we think of an experimental school in terms of 20-child classrooms as if the 20-child classroom or the 30-child classroom or, for that matter, the classroom had some demonstrated validity as an instructional setting. The rules and procedures underlying the arrangements of schools exist for reasons of history and culture, but these reasons have little to do with learning or with children. The rules and procedures exist because they make the present system of education manageable. The interests they serve are not those of children, or of learning, or of society at large, but those of the school administrators, the teachers, and the parents.

Let me illustrate by means of a horrible example. The basic problem faced by any school is what to do with the children. Let us say that there are 800 children in a neighborhood. Of this number, 420 are considered for some reason to be of "elementary school age." That is, they are older than five and probably no older than twelve. These 420 children must by law be in school for a minimum of 6 hours a day, and they are supposed to learn something. Putting aside the more interesting question of what they must or should learn, how does one go about organizing them into teachable groups?

Tradition dictates that you, as principal of this school, will be provided with roughly 1 teacher for every 30 children, or 14 teachers. It is simplest to divide the children into 14 groups of 30 and to place one teacher in charge of each group. But on what basis do you determine which child should enter which group? The most obvious criterion is that of age, and so all 5-year-olds become kindergarteners, all 6-year-olds become first-graders, and so on. This gives you two kindergarten classes, two first grades, etc. This arrangement has an advantage. It provides you with a simple solution to the problem of how to construct a usable school building. Allot to each class a cozy enclosure and string them together down two sides of a central corridor, rather like an egg-crate:



Add a gymnasium and a cafeteria, and presto—a school!

Now it is possible for you as principal to face the problem of what to teach and how to teach it. It is not difficult. The first order of business is to make your illiterate charges literate. Therefore, all first-graders begin to learn to read, write, and spell; and this, obviously, should continue progressively through the elementary school program. Similarly, all children should have some science, math, social studies, and perhaps some art and music. Out of convenience, you divide the substance of each subject into seven blocks, each progressively more "difficult" than the previous one, and assign the "easiest" block to the first-grade teacher, and so on up through the sixth grade.

You can be proud of this system: It is tidy, it runs smoothly, and the parents and the community are happy. You are a successful educator. But after a while, if you are a perceptive fellow, you begin to notice that the children somehow do not quite fit the Procrustean bed you have so carefully designed for them. Some of these first-graders appear to be brighter than others and some of these are bored to oblivion. Others don't quite "cotton" to the curriculum or, indeed, to school. In fact, what you discover is that very few children fit with *any* degree of comfort into your scheme. This is not surprising, since you did not design either the system or the curriculum for their benefit, but still it bothers you.

So you begin to tinker with the pattern. This is not easy, because you have built your system well. In addition, it is backed by 100 years of history in this country and by traditions older than yours. Your culture approves it, and it is further fortified by the schools of education which trained both you and your teachers and by the various professional organizations to which you all belong. But you try.

You settle on a slightly different method of grouping the children. Instead of dividing your 60 first-graders haphazardly into 2 classes of 30, you put the ones who score high in IQ into one class and the ones who score low into another. This is called homogeneous grouping, and it is a partial solution to the problem of the boredom of the bright and the bewilderment of the dull, but it generates a host of other problems.

You now have to design two separate curriculums, or at least water down the one you give the lower group. By the time these children get to high school they find themselves glued to one of four tracks—academic, general, commercial, and (dreadful word) terminal. There are other problems: elitism among the bright, apathy and anti-intellectualism among the dull, parental disgruntlement, and many more.

But the real problem is the old one. All the children—bright, middling, or slow (whatever these terms may mean)—are still not learning much and still not liking school much. You are driven to further tinkering in the form of team teaching. You abandon your system of encasing 1 teacher and 30 children in one unalterable unit. Instead you take four such classes and their teachers and toss them all together. The teachers now cooperate in planning their curriculum and in grouping the children. They are now in a position to draw from the group of 120 all those children who are facile arithmeticians. This group of perhaps 20 children can study math with the teacher best qualified and most interested in teaching it. The children are then returned to the large group, and a new group and a different teacher is assigned to the advanced English class. You have made it possible by this arrangement for children to be more precisely grouped according to their particular abilities in particular subjects and to be taught by the teacher best suited to teach each subject.

You go farther. You try to get rid of the grade structure. Under the existing, arbitrary pattern each grade equals 1 year's effort, and the curricular structure decrees that each child must cover a prescribed amount of material during the course of the year. Pace, therefore, becomes a matter of deep concern. By breaking down the grade barriers, you have rid yourself of the expectation that all children can or should devour the curriculum in exactly equal gulps in exactly equal amounts of time. Now the children can digest the curriculum you have set at their own most appropriate rates. You have by no means removed all temporal constraints from your program, of course. There are still rigidities in each day's schedule. Bureaucracy dictates that the day must be divided into periods! Even if the class is on the threshold of mathematical discovery at 12:15, it must quit and line up for lunch.

As you begin to loosen up your program, you begin to put more faith in the self-propelling abilities of children, and you find that you want them to be able to spend increasing amounts of time exploring on their own. This is an admirable notion, but you find that there is simply no place in your school where the children can do it. Your library is an abandoned classroom with only a handful of books, few chairs, and fewer tables. Since what you have in mind is not the old spitball study hall, you find yourself in the awkward position of being forced to go to the superintendent and the school board to request the one thing they are most loath to give you—more money, so you can buy more books, more maps, charts, films, pictures, chairs, tables.

But this is not the end. It is clear that in addition to a new library or an independent study center what you really need is an entirely new school building. For in your tinkering with new ways of grouping children and teachers, you have found that it is very difficult for teachers to group children in a wide variety of ways and in groups of widely varying size if all of the rooms in the school are unalterably 30 feet by 30 feet. The room is always too large or too small.

Moreover, you are now involved day and night in laborious logistics: Where are all the teachers and the children and what are they doing? Where can you put them? You have a scheduling problem that, in fact, can be adequately handled only by a computer. And you can be quite certain that, if you ask for a new school building and a computer at the same time, you are not going to be the next superintendent of your district.

It comes to you, finally, what you have done: You have almost entirely subverted the existing patterns of school arrangements and the assumptions which support them. You are sure that the old way was wrong, but you are not really sure of your new ground. You have no support from the establishment of your profession. The school board and the public do not understand what you are doing. And you cannot point to any solid, respectable scientific research to "prove" that what you are doing is right or even sensible.

* * * * * * *

It should be clear from this simplistic example that school arrangements, like most institutional arrangements, are resistant to the introduction of new ideas and that they grow up, not as a result of scientific inquiry, but bit by bit in response to immediate needs, often of a bureaucratic nature. For the curriculum-builder and probably for those engaged in short-term instructional research, school arrangements are important considerations. Those involved in short-term research should inquire into the validity of these arrangements. What, for instance, are the consequences of various systems of grouping, in terms of the cognitive and emotional development of the child? Even the physical surroundings in schools could merit some attention. If wall-color can affect remembrance of nonsense syllables in the laboratory, then surely carpeting, room size, and air conditioning may influence a child's learning in the classroom. The educational facilities field quickly lapses into gadgetry—which folding wall folds better?—principally because of the lack of data on the effects of physical arrangements on the instructional process.

But if these questions bore you, there are deeper questions, and it is with these, as psychologists interested in long-term instructional research, that we should occupy ourselves. One such question concerns the criteria for grouping. These are exceedingly limited, usually based on nothing more than an IQ score—hopefully an individual IQ test, but more often a group IQ—with perhaps a smattering of emotional stability measures. IQ is an adequate predictor of school achievement, as achievement is currently measured and defined and allowed to operate in the school setting. It is this last that is crucial. IQ groupings often serve to mask instructional failure: By putting the blame on the child's native capacity, the schools can escape the unsettling possibility that it is perhaps their own technology that is at fault. Consider the children studied by Kuhlman. These were children of equal IQ, but some were high in imagery and others were low. Those who were high in imagery learned to read more quickly than those who were low; low imagers were better in other fields. If these children are put into classrooms on the basis of IQ, then they will be homogeneous with respect to IQ but heterogeneous with respect to what we might call mode of learning. If we group them according to achievement—as would happen in an ungraded school—then the high imagers would be together in reading class, the lows together in math class, and so on. But in neither case would the school be meeting the instructional problem, if that problem is to teach each child in a way consonant with his proclivities. You have solved the problem of pace, perhaps, in the upgraded situation; in the IQ-based grouping, you have solved nothing at all. Preferred representational mode, then, or cognitive style, or what you will, might provide as rational a method of grouping as IQ. A curriculum that is courteous to one child may be exceedingly discourteous to another. Perhaps we need a plurality of grouping criteria. It is with the discovery of such dimensions that we should be concerned.

We need more research—laboratory research—on the basic question of learning in groups. Is there an optimal group size for learning? Or is this a practical matter of how many children a teacher can attend to? How many *can* she attend to? What are the conditions determining optimum group size? Are there transcurricular optima or does it depend on the subject under study? The age at which a child should enter into formal instruction is only one of a number of researchable questions which emerge when once we allow ourselves to think of instruction outside its conventional context. It is true that many of these questions are decided, not on the basis of psychological data but on the basis of practicality and value. Questions of public policy—and team teaching is such a question, perhaps—are ultimately a matter of value. But these values, at least in education, are likely to be incorrect extrapolations from misunderstood scientific data. Children *should* start to school at six because school is to teach people to read *and* children cannot learn to read before they are six and can learn to read after they are six. Presumably, the child whose sixth birthday occurs at 2 minutes before midnight on January 1st is ready to read, whereas the child born 2 minutes later is not yet ready.

CHARACTER EDUCATION AND CURRICULUM

Jerome S. Bruner

In an effort to divorce their enterprise from the moralism that permeated Victorian conceptions of man, psychologists long ago introduced a distinction between "personality" and "character"—the former views the nature of man naturalistically and from an ethically neutral point of view, the latter with an evaluative perspective. But it has also become apparent over the years that the formation of a personality could not be divorced from the nature of the culture in which a man lived. Each culture has its own value system and its own view of the good, which perforce becomes operative in personality. Thus, the study of personality must investigate the "fit" between an individual's values and the values of his society. Terms like "deviance" and "socialization" are standard in referring to the growth of personality.

Any educational effort—and curriculum building is no exception—is an extension of a society's effort to socialize its members. There is no sharp line between socialization in the family, in the market place, and in the school. Education in most primitive societies, Spindler has pointed out, is usually a combination of theology and "the liberal arts." Vocational preparation is usually done in the context of the family and takes the form of apprenticeship. The function of "education proper" is to introduce the young man or young woman entering the society to the founding myths and rituals that bind together those who share a common body of practice and doctrine. But it also has the function of shaping personalities to conform to certain ideal types—not only in the "moral sense" but also in the sense of how mind is used. Any society must be concerned with the image of its wise men or prudent men or effective women. As such, education is covertly or overtly concerned with the forming of character in some sense, with the forming of it in some way that reflects conceptions of the good life, the good man, and the good society.

We have been insistent in this report in remarking that intellectual character is not isolable from the emotions and attitudes of a human being. Honesty and courage exist not only in the conduct of daily life but also in the process of solving intellectual problems. But character traits like honesty and courage cannot be formed in the classroom unassisted by the rest of life. They stem from the more intimate interchange of family and friends. But honesty and courage can be extended, strengthened, and deepened by being related to the use of mind in the classroom. The impulse to honesty cannot find expression in mathematics or history or poetry without some practice in exercising honesty in these activities. Education then provides vehicles for extending the range of character. Perhaps we can best illustrate by reference to the study of history. One probably learns compassion in the closed circle of one's family. It is an early model, a "first edition" for a way of seeing, feeling, and behaving. If one never learns the communality of man's plight, never recognizes that the major vicissitudes are shared by all men in any society in some form, the result is often a man gentle in the confines of his family and brutally chauvinistic towards "foreigners."

There is ambiguity in Anglo-Saxon culture about the relation of virtue on the one side and innocence and knowledge on the other. The romantic ideal, with its sentimentalization of agrarian simplicity, often portrays "simplicity" as a guardian of individual virtues. Learning and knowledge, like the fruit of the forbidden tree, are seen as sources of evil and corruption. Yet however much we may admire the Lake poets and the romance of the countryside, the world has gone on to becoming more interconnected and more complex. Humaneness, while it may be essentially local in its origins, now becomes compellingly universal in its applicability. Today the exercise of a broader humaneness may virtually be a condition for human survival. And most strikingly, the exercise of humaneness requires today a technical and social competence never before required. To be effectively humane requires a working model of industrial society, of the limits and capabilities of science, of the constraints of history, of the possibilities of government.

All of these considerations lead us to inquire anew about the desired impact on character which we might want our schools and their curriculums to xert. Anything beyond a minimum list of things to be hoped for would be both pretentious and unrealistic. A condition for achieving social goals is that one limit objectives to the power of one's resources. The resources in this case are schools, teachers, books, and exercises. We believe that the objectives set forth below are attainable within the limits of such resources and by their wise use.

A first constellation of character traits that seem capable of being formed or encouraged within the school has to do with respect for one's own capacities. Perhaps the one most pervasive thing that prevents man from reaching his full potential is a lack of confidence not only in his own capacities but also in the ability to develop them further. It is often as deep as man's image of himself. We believe that schools by their present practice, and quite unwittingly, often foster such a weakened self-image. The various suggestions and proposals that appear in these pages concern precisely the kinds of curriculum changes that may produce a change for the better in this sphere—encouraging children to discover the goodness and corrigibility of their own guesses, to discover the utility of first-order approximations in entering a problem, to find out the activating effect of trying out an hypothesis even when it seems a wrong one. We do not know with certainty whether such measures will succeed, but there is sufficient evidence to encourage efforts along this line and research in support of such efforts. This is not to say that the schools be urged to foster arrogance and a spirit of know-it-all. Confidence in one's capacities is not arrogance.

This brings us to a second major aim: the development of confidence in the solvability of problems by the use of mind. We would urge that intellectual modesty grows out of a sense that problems can be solved by the use of mind, that things are usually neither obvious nor hopelessly beyond solution. Modest optimism such as we describe here is, we believe, a concomitant of the confidence discussed directly above. But there is one feature of this optimism that is worth special attention. Inert knowledge about something is not what gives one confidence in the solvability of a problem. Rather, what prevails is understanding backed by a sense of how one gets and how one transforms knowledge. The confident sailor is rarely the unskilled one. Confidence is the gift that comes from mastery of how to operate. We have argued at various places in the report that in teaching history we give the student a working sense of the methods and conjectures by which the historian operates, that in imparting the mysteries of mathematical order we teach the student the ways of mathematical thinking and not just its results. These are the sources of confidence in history and mathematics, and the same can be said of any discipline.

The third aim is self-propulsion. The object of a curriculum is to lead a student to operate on his own—for with respect to any given subject matter, a human being will be on his own most of his life. In many curriculums now being devised, there is strong and commendable emphasis on letting the learner deal directly with the materials to be mastered, letting him locate the form of the problem. An elementary science course now in preparation, for example, gives children ample opportunity to play with a balance beam and to discover regularities in the phenomena of inertial physics. It is only when the child has enough intuitive "know-how" to sense what makes sense and what does not that the teacher enters to help him formulate his conjectures. This type of confrontation with materials, this practice in being problem-finder and problem-solver allows the child to become a partner in determining when he is right and when wrong, when relevant and when irrelevant. It is preparation for operating on his own.

A fourth aim, and it is perhaps a little surprising to call it "character," is economy in the use of mind. Mathematicians describe their kind of thinking as using your head to find a way around a difficulty by easier and better means. One hopes to create in a learner a drive to look for relevance and structure. For it is this drive that in the end gives the student an attitude of suspending surfacy first impressions, encouraging him to look beneath the surface for less obvious and more powerful things. The virtue is reflectiveness. And we believe that there are exercises that can be imbedded in a curriculum that will in fact increase this highly desirable trait.

Finally, we would point to intellectual honesty. What characterizes intellectual activity to varying degrees in different subject matters is its corrigibility by various forms of evidence. Honesty intellectually is an eager willingness to use the apparatus of a discipline for correcting one's solutions, one's ideas, one's notions. In some fields, it is a matter of minutes to check—e.g., mathematics. In science, the process of experiment may take longer. In historical analysis, the process of checking out takes longer still, requires a more circuitous and uncertain path. We feel that students can be brought to an appreciation of the forms of intellectual honesty not just in one field but in the various disciplines in which man has learned to use his mind and his sensibilities. To achieve honesty of this kind across the range of fields to which one is exposed is not easy. It requires honest teaching without defensiveness or sham. It requires an appreciation of how honest minds work on both sides of the imaginary line that separates the "Two Cultures." And in a most practical sense, it requires the preparation of text and work materials that exhibit this honesty in a palpable form. Texts that drift easily over the unknowns and substitute catch-phrases for admissions of ignorance provide poor models. Nor can dishonest "easiness" be justified on the grounds of "making things simpler for the students." A high school physics course has been particularly successful by presenting two, unresolvable physical models of light —a particulate image and a wave model. It leaves the student with the same type of conjecture that the working physicist has. It is surely no luxury to leave the student with a sense of problem when the very field he is studying is beset by it. We do not know how well and by what means intellectual honesty can be taught, but it strikes us that many worthwhile experiments can be undertaken.

One could easily go on to other characterological aims of education. We have no doubt that the school contributes to the child's willingness and ability to participate in the process of communal living. Nor do we doubt that schools contribute much by teaching the underlying values of the American creed. Surely it is the duty of the school to do both of these. But it is far from obvious how one achieves either of these objectives effectively. We deplore the explicit emphasis found in some schools on "getting along well" with one's fellows—almost presented as a manipulative instrument for "getting on" in general. Insofar as schools succeed in teaching the virtues of communal living and its techniques, they probably do so by providing models of decent communal living. And with respect to the creed of the culture, it is surely not by the boastful recounting of our virtues and the shortcomings of our enemies that we instill respect for our way of life. What is striking about the American culture—and what is so difficult about summarizing it—is that it exhibits a faith in a process rather than in any particular product or attained resultant. We are remarkable for our capacity for orderly change and growth, change and growth while maintaining an underlying stability through respect for processes of guaranteeing individual rights, responsibilities, and initiative. In a deep sense, processes are best understood by living them and by examining well what it has been like as they were lived under other, even more trying, circumstances. An appreciation of the American past and present is an appreciation of a process at work.

It is in this sense that, in these pages on characterological objectives in education, we have emphasized in such a degree the training of our students in the use of mind—the use of mind with confidence, energy, honesty, and technique. It is in these processes that we place our confidence, not in any particular outcome.

CURRICULUM: EDUCATION AND RESEARCH, THE CHANGING PATTERN OF CURRICULUM CONSTRUCTION

Lloyd Morrisett

The years since 1950 have witnessed basic changes in attitudes toward American education, and these changes are perhaps best exemplified in changing patterns of curriculum construction. Laissez-faire attitudes toward course construction and the production of materials are being challenged by curriculum projects which show far more self-conscious concern for the selection and sequencing of materials in the *design* of entire courses. The curriculum project has become a highly important agent of change in education. It also has become both a main impetus for devising a satisfactory theory of instruction and the practical embodiment of whatever theories of instruction currently exist. Devising a research strategy that will result in a satisfactory theory of instruction and the implementation of that theory of instruction in the classroom are problems inextricably linked to the curriculum project and its origins in American education.

Variety, Selection, and Coverage

The traditional benchmarks of curriculum building in American education are variety, selection, and coverage. With small difference between grade school and college, we have believed in competition in the production of text materials—each producer to determine for himself the subject matter to be included and the method of handling. The reported virtues of this approach were the existence of a variety of materials dealing with the subject matter to be included at any educational level. The materials differed in quality, in content, in level of handling, and in the goals of their construction. Given variety, it has been the responsibility of the teacher to select those textbooks and other materials that best suited the needs of individual courses. In this version of local control it has been believed that the person closest to the classroom is the best judge of what should constitute a proper course. The one most general criterion for both the producers of materials and the selectors of materials has been coverage—a body of information made available to the student.

The Curriculum Project

Since about 1955, the curriculum project has been developing as an alternative to the more traditional laissez-faire methods of curriculum construction in America. Renewed emphasis on education and educational improvement accompanied by wide public debate has raised doubts that such an important matter as curriculum construction should be left to the vagaries of variety and selection. Increased public concern about education was perhaps a natural aftermath of the anxieties of World War II, but it was given added impetus by Cold War competition and the belief that America's long-term strength was very much dependent on the success of its educational enterprise. In 1953, Dael Wolfle's study, *America's Resources of Specialized Talent*, was published, and this study along with others began to put education in the framework of national strategy. At first these strategic questions were principally about the selection and identification of students and their choices of fields and occupations. However, a natural turn was for questions of curriculum construction to be put into the same framework. Manpower needs were becoming obvious and it was also obvious that a successful national program did not depend solely on the processes of identification and selection but also, and crucially, upon the cumulative efficacy of individual courses.

Faced with these broad educational issues, scholars began to take a look at elementary- and secondary-level curriculums in their own fields. Short acquaintance convinced many that present curriculums did not satisfactorily represent their disciplines. With this as a starting point, the scholars were quick to realize that early education in their own fields provided the foundations for college recruitment and graduate education. Enlightened self-interest, if nothing else, dictated that elementary and secondary education be of the highest quality. A number of attempts to devise new curriculums were begun, and it was widely recognized that both college and university personnel and schoolteachers were needed to insure that the materials were sound in content and teachable in form. The typical curriculum project was organized and administered by personnel at the college level, but experienced teachers were involved both in the writing stages and in the tryouts.

Assumptions and Goals

The curriculum project has been based on several assumptions.

The first is that existing curriculums in the elementary and secondary grades do not satisfactorily represent the conceptual structure of advanced disciplines. It has also been assumed that new and important material is not widely included in these existing curriculums, and that these two deficiencies greatly decrease the value of elementary and secondary instruction. Another practically universal assumption is that the sequence and choice of material in a curriculum are highly important; in some sense a curriculum should mirror the conceptual structure of a discipline. Particularly in mathematics, physics, and the other sciences, it is believed that certain units are necessary to lay the groundwork for further work. Units should be arranged in some logical sequence in order to insure appropriate foundations for later learning. The emphasis here is on the arrangement of materials rather than on their presentation, although most curriculum projects give considerable attention to devices for presenting their materials in attractive and understandable ways. All of these assumptions imply less dependence on the individual teacher's expertise and judgment in the choice of materials. New courses are tightly knit and sequentially organized, and while there is room for individual variation in teaching procedure, the range of this variation has been very considerably reduced.

Finally and perhaps most importantly, the curriculum project has proceeded on the basis of a set of goals for education that are long-term in nature and explicitly stated. While these goals have not been altogether absent in former curriculums, they have certainly not received the same emphasis and attention. The criteria may vary from one curriculum project to another, but in general they involve a conceptual understanding of the discipline, the development of positive and creative attitudes toward the field, and individual creativeness. It became very much less important that an individual could solve a given problem than whether he could learn new concepts and enjoy their mastery. It might be said that the aims of the curriculum project are to develop individual potential—whether as mathematician, physicist, or chemist—insofar as that potential exists.

Research and Evaluation

The curriculum project has been a bold innovation in American education and has achieved much. As the work has gone ahead, however, a number of intractable problems have had to be faced time after time. The curriculum builders as well as their critics have found that an optimal curriculum cannot necessarily be based solely on teaching experience and a thorough understanding of the material. Decisions about sequencing and arrangement of materials, about what to include and when to include it, about generalizations and example, about direction and discovery, cannot be resolved without a theory of instruction. For a time it was believed that learning theory provided the basis and framework for a theory of instruction. But it quickly became apparent that this was not the case. Learning theory may contribute importantly to a theory of instruction, but a theory of instruction must contain propositions that are applicable in curriculum development and teaching. Another set of problems in the curriculum project revolves around adequate evaluation. New criteria for education demand new means for evaluating the material. Evaluation is necessary not only to make judgments about individual achievement but more importantly to diagnose and remedy deficiencies in the curriculum. Most existing tests were found to be completely inadequate or perhaps based on different assumptions about education. In summary, the curriculum builders found strong need for contributions to their projects by social scientists and educational researchers, but also found that relevant help was in short supply.

Evaluation as a Component of Research

The importance of evaluation to curriculum construction is widely professed; however, no one seems content with present techniques. In education the term "evaluation" has heavy connotations of measuring pupil achievement or rating the success of a course. Perhaps the most important lesson here is that evaluation, particularly in relation to the curriculum project, must be seen as an integral component of research on instruction. It is true that measures of pupil achievement or the means to assess an overall project may develop out of instructional research, but it is argued that these should not be the primary aims of instructional research and even that these outcomes will be best pursued by concentrating on more basic aspects of instructional research.

In addition to putting evaluation in the framework of instructional research, it has been found important to build this research into the curriculum project at the very beginning. Instructional research is best developed cooperatively among the social scientist, curriculum builder, and teacher. Attention to evaluation, among other research goals, at the beginning of a project can help clarify and make explicit educational assumptions. These, in turn, provide grist for a theory of instruction. Also, it becomes apparent that means of curriculum criticism must be devised to provide feedback to the work. If evaluation is put off to the end of the work, it loses much of its relevance. Existing techniques are often found to be inadequate; necessary input data may be unavailable; and the result is that evaluation becomes a meaningless exercise rather than a necessary component of research.

Feedback and Criticism

In order to have the information necessary to improve the products of his effort, the curriculum builder must find ways to obtain knowledge of the results of his work; and to be of real use, the knowledge of results must be available during the course of the project. This implies that a curriculum project should have means of obtaining continuous feedback about the products of its work both from pupils who will utilize the materials of the project and from independent experts.

The field of programed instruction provides a useful paradigm at this point. One of the main tenets of programed instruction is that the program, or instructional material, creates the conditions for successful learning. If a pupil does not learn successfully from the program, it is not the fault of the pupil but the material. This means that programs must be developed by a process of continuous tryout and revision based on pupil performance. The program writer proceeds by preparing a small section of material and trying it out on a few students. He examines the students' behavior—the errors of learning that occur, where there is lack of understanding, where the material seems redundant—revises it, and tries it out again. This process is continued until some criterion of successful development is reached. The cycle is repeated on another section of material. At the end the sections are put together and the process repeated again on a larger group of students. This means that programs go through a continuous process of tryout and revision. Although not everyone would agree with all the assumptions of programed instruction, it is clear that this method of continuous tryout and revision brings great gains in clarity of material, organization, and choice of content.

This leads to at least one suggestion for a criterion of successful curriculum development. A given curriculum might be translated into the form of programed instruction, and after that, independently translated back into a textbook or whatever the original form was. The degree of discrepancy between the back translation and the original version could give a measure of successful curriculum development.

Whether this be the answer or not, it is clear that curriculum construction needs to evolve in the light of two kinds of criticism: one from independent experts who have not been involved in the project; and the second, perhaps more importantly, the kind of criticism that can come only from student performance.

Long-Term Assessment

Comments up to this point have been devoted to short-term evaluation of curriculum projects; long-term assessments are also necessary. Short-term evaluation alone will not provide answers for the curriculum builders when they ask whether their curriculum enhances creativity in students, leads to individual initiative with the material, or to greater numbers of students choosing a particular field in graduate school. Nor can short-term evaluation help answer all of the theoretical questions that the psychologists ask about the learning process. The same comments about building in research at the beginning of a project and developing satisfactory methods for continuing it apply to long-term assessment and need no restatement.

Institutionalizing Change

Curriculum construction, teacher-training, the teacher, and research are inextricably linked in the process of education. The curriculum builder is dependent upon new research information in order to improve his work, just as he is dependent on experienced teachers for knowledge of the classroom and the limits of instruction. He cannot be satisfied that his curriculum will be used correctly unless it is incorporated into teacher-training programs. Similarly, the researcher draws problems from curriculum projects and sees his research carried out in the classroom. While this may be true, we have tended to separate research, curriculum building, teacher-training, and classroom performance and so have lost the manifest advantages of close linkage. The real issues are highlighted when we consider the problem of institutionalizing curriculum change.

Emergencies, whether in wartime or in education, do not last forever, and those who are concerned with educational improvement cannot depend upon emergency motivations for the continued energy necessary for educational advance. Although much can be done on an emergency basis, and certainly the curriculum project has accomplished much, one possible outcome of emergency action is a freezing of the results of that action. Only infrequently can a group of specialists be brought together and asked to give freely of their time over and above long-term commitments to teaching and research. The amounts of talent and money given to a curriculum project may stand as strong deterrents to those who would try to devise something better. Given the results of the curriculum project and its conclusions, it may well be thought that significant improvement can occur only if an ever-greater concentration of talent and money is brought to bear. At present, the necessary collection of people with the variety of appropriate skills does not have a natural home in which to operate. Academic departments of our colleges and universities do not, on the whole, have the requisite broad concerns. Our schools are concerned with the process and products of education rather than devising means for its improvement.

Over and against this are the indisputable facts that disciplines continue to change, classroom conditions continue to change, and the accomplishment of pupils continues to change. All this means that it is necessary to institutionalize the process of curriculum development and change. Without some satisfactory means of institutionalization, it will not be possible to conduct the long-range research necessary for continued improvement, nor will it be possible to let the development of curriculum materials and the development of a satisfactory theory of instruction proceed by the necessary stages of successive approximation. Given America's educational aspirations, contrasted with our altogether inadequate knowledge of the instructional process, and combined with the advance of knowledge, no one can be satisfied with any present curricular accomplishment. It is clear that we will have a better chance of improving results if we can find ways of institutionalizing curriculum change and research and at the same time maintaining the advantages of pluralism.

The Experimental School

The experimental school is by no means the complete solution to the problem of institutionalizing curriculum development and change, but it is a very necessary ingredient of the solution. At present it is difficult to create the conditions for good, long-term instructional research. Facilities are inadequate, schools are overcrowded and oriented in other directions, and there is no good organization to support and direct research.

The experimental school is conceived as an operating school specifically designed as a vehicle for long-term instructional research. It would be closely tied to curriculum projects and to teacher training. Taking just elementary education, requirements would be that the school range from grades K–6, with at least two classes per grade for minimum experimental design. The school population should approximate a normal distribution with regard to ability and social class and should be drawn from a geographically stable population. As teachers would be the primary research instruments, there would need to be probably at least twice as many teachers assigned to the school as needed in day-to-day instruction. Those teachers not teaching would be helping develop research programs and learning research procedures. The curriculum project would naturally feed materials and problems to the school. The school would probably be directed by a qualified principal and a research director as well as advised by a research committee. Location near a university would clearly be helpful. Research problems would not be chosen simply for short-term payoff but for their long-term contribution to a theory of instruction. To raise the probability of experimental payoff and to minimize dangers of isolation and provincialism it would be desirable, if not critical, to establish several experimental schools, although a beginning with one would be useful and help point up difficulties.

The proposed experimental schools are predicated on the dual propositions that conditions must be created for good instructional research and that a planned research effort will in the long run be least costly and offer the best returns. A final proposal then is that the area of instructional research not be left to the whims of its own self-development. A competent advisory body should be constituted to assess periodically the progress of the development of a theory of instruction and the quality of the operation of the experimental schools. It need have no power further than making its findings public, because their relevance to the experimental schools and to the state of research would be apparent to all concerned.

Recruitment and Training

Trained manpower now available for mounting the kinds of efforts discussed in this report is in very short supply. There is a critical shortage of appropriately trained psychologists; educational researchers in general do not have sufficient background in the fields of learning and problem-solving; and in particular there is virtually nobody available with developed skills in subject matter fields and in behavioral analysis.

We believe that there are several rather straightforward ways in which this situation can be remedied.

The Intellectual Climate.—More and abler people are being attracted into educational research and development as a result of the interest being shown in this work by leading scholars in the sciences, mathematics, psychology, and various other subject-matter fields. As far as psychology is concerned, there is one special factor that is drawing leading psychologists back into research on education. It is that research on learning and thinking takes on a new richness and depth when put in the context of instruction. An orientation toward educational problems on the part of a psychologist is not simply an exercise in application; it can be as much an extension and generalization of psychological theory.

Special Educational Programs.—To train men and women to carry out research on the processes of instruction and "instructed learning" requires at least three kinds of instruction. First, instruction is needed in the psychology of learning, problem-solving, and development. Secondly, training is needed in the core disciplines of education, including measurement, educational philosophy, and the like. And finally, it is highly desirable that the aspiring researcher have some solid background in one curriculum field, be it mathematics, biology, literature, or geography.

It is possible to recruit people to a career in "pedagogical sciences" from psychology, from education, and from various substantive fields. Recruitment among psychologists probably comes principally from the examples of distinguished psychologists who are now showing a quickened interest in education. The more research-minded men and women working for degrees in education can readily be recruited. And finally, with respect to the attracting of young scientists, historians, and the like, the following point can be made. There are only about 300 Ph.D.'s in education awarded each year by American graduate schools. But many times that number graduate from college with undergraduate majors in mathematics.

The course of studies leading to a "Ph.D. in Educational Research" along the lines discussed in this report should be flexible, indeed tailor-made for individual students. It must be taught jointly by psychologists, those education specialists with the relevant skills, and by substantive specialists. In some universities they will be physicists or mathematicians, in others linguistics, in still other literary critics. The programs will surely vary and will necessarily be *ad hoc* in the beginning with respect to staff and to programs.

Three things will contribute to their stability as well as their drawing power. To these we turn next.

Fellowship Grants

In a day when competition for able men expresses itself in part by the provision of scholarships and training grants, a program such as we propose here must have some provision for the financial support of trainees. Training grants are not now available, save in certain fields covered by special titles in the National Defense Education Act.

Research Centers

An opportunity for apprentice training on research in progress is one of the most attractive things that can be offered to an eager graduate student. Training programs should be started only in those institutions where curriculum research is now in progress, curriculum research involving a real collaboration between substantive specialists, psychologists, and educators.

Job Opportunities

As the efforts in curriculum construction progress, there will undoubtedly be a greatly increased number of jobs available in faculties of education. This, too, will lend increased stability to the training enterprise.

THE CURRICULUM RESEARCH TEAM

Jerome Bruner

The problem of research on curriculum development is, on close inspection, a variant of the more general problem of corrective feedback. That is to say, it is a question of carrying out research that can be of some service to the curriculum maker while he is at work on a curriculum and at the points where he can most benefit from knowledge of results. Up to the present time, most educational research related to curriculum has served this end poorly. Typically, a curriculum is built and "tried out" in a most informal way, the principal feedback coming from teachers who are using the materials in a class for the first time. After this stage, the curriculum is tentatively formalized, usually in mimeographed trial texts, teachers' manuals, and exercises, and the evaluator enters the scene. His usual procedure is to design a psychometric testing instrument that measures the achievement of children "taking" the new curriculum (often in comparison with a control group of children who are being instructed by some more traditional method). After evaluation of this kind is completed, the results are then summarized in terms of relative achievement in relation to the aptitude, age, socioeconomic status, and other characteristics of the children who have been involved.

The shortcomings of this way of working are obvious. In the first place, the information obtained by the evaluator is usually too late to be of much use in the actual structuring of a curriculum. More seriously, the evaluative results are rarely in a form that can be of direct aid to the curriculum maker in the decisions that he must reach about how to present material, what material to include, what kinds of exercises to devise, and so on. An account of relative achievement is peculiarly unhelpful to the curriculum maker. And finally, the procedure does not make provision for a close and continuous working relationship among the curriculum builder, the teacher, and the evaluator (usually a psychologist or educational measurement specialist). Indeed, often the trial teachers during the evaluation phase have no clear idea of what the curriculum specialist had in mind (and vice versa with respect to the latter's recognition of the former's problems) and the evaluator has little sense of the needs and aspirations of the other two.

We feel that this pattern of work is the result of several decades of accidental growth in practice, and that it is neither necessary nor desirable to continue in this way. The current revolution in the conception of curriculum making suggests, we believe, a counterpart revolution in the way in which research should be conducted in its support.

Consider as a reference model the way in which research is carried out in psychiatry, in particular, research on the effects of different treatments. To begin with, the work is organized around the concept of a "team," typically consisting of a psychiatrist, a psychologist, and a social worker. The psychiatrist is concerned with day-to-day therapy, but he does not operate in a vacuum. Reports from the clinical psychologist and the social worker guide his tactics of treatment. We do not wish to propose an analogy here, only to highlight the importance of "feedback as you go." Consider now the nature of the "team" that might operate in curriculum building and testing.

The ingredients are fairly obvious. For one thing, the curriculum builder needs detailed information as soon as possible concerning the comprehensibility of his material, the extent to which it produces activation in pupils, what kinds of blocks to comprehension are developing, how well the material transfers, etc. All of this needs to be related to particular pieces of curriculum—a particular topic or exercise or demonstration or set of paragraphs in a book or manual. This means, in effect, that the curriculum builder needs a try-out teacher working with him and also a psychologist who can observe and test in detail with respect to agreed-upon objectives. The teacher must be well enough trained and acquainted with the objectives of the curriculum project to change pace, re-present material, and make possible new observations by the psychologist. The working core, then, includes a curriculum specialist (with as deep a knowledge as possible of the particular subject matter), an experimental teacher, and a psychologist trained in close observational techniques for the study of problem solving techniques, that are closer to the tradition of Piaget than to psychometric test-construction.

Lest the account above seem in the spirit of an engineering suggestion, several points should be added. To begin with, the work of the psychologist in the team will be more helpful if it is guided by broad theoretical notions. Many of the hypotheses and research proposals contained in the present report set forth or imply just such broad theoretical guidelines—matters related to development of attitudes, control of stimulus materials, and activation and strengthening of certain cognitive skills. Insofar as a team venture is to be successful, it must be based on some optimal mix of the curriculum specialist's knowledge of the structure of his subject and the psychologist's knowledge of the structure and development of human capacities and skills. Secondly, it is quite plain that the development of a theoretically based psychology of instruction will depend upon a careful working out of generalizations in the particular contexts of different subject matters. This is not to say that in the end, each branch of knowledge will have its own "psychology of . . ." Rather, the object is to find some means of strengthening our general propositions about instruction by comparing and condensing the findings of studies on such verbal material as history, such highly symbolized material as mathematics, such manipulative materials as one finds in elementary science, and such affectively toned material as one finds in the field of literature.

Our basic proposal for the working team of curriculum builder, psychologist, and experimental teacher serves the purpose then of increasing the effectiveness of curriculum building on the one hand while contributing to the eventual power and coherence of a theory of instruction.

CHAPTER III

REPORT OF THE WORK GROUP ON STIMULUS CONTROL

A BEHAVIORAL APPROACH TO INSTRUCTION: GENERAL STATEMENT OF RESEARCH PROBLEMS AND STRATEGIES

Members of the group: Roger Brown, Margaret Donaldson, Jacqueline Goodnow, Harry Levin, Frank Restle, Patrick Suppes

Suppose we start with a recurring question: *How do we get a child from an initial state A to the aimed-for state B as efficiently as possible?* This is a question that arises in a number of contexts:

—In improving a specific part of a specific curriculum.

—In developing some general framework that will allow us to describe the features of curriculum, or the degree of fit between its content and its aims. We have at present only rather gross terms —the sequence of chapter-size topics, for example—for comparing one curriculum with another.

—In any psychological discussion of learning or problem-solving.

The question—"How do we get the child from state A to state B?" —is not simple, and we see no feasible way to answer it until we ask:

1. What is the initial state A?
2. What is the aimed-for state B?
3. What are the sources of difficulty in moving from state A to state B?
4. How can we remove the sources of difficulty?

These questions are to be answered by examining, not a whole curriculum, but a small unit of content or a smaller set of classroom occasions.

In general, we would suggest choosing for examination those points where the children or the teachers run into significant difficulties. An example may be taken from Karplus.[1] Karplus observed, while teaching the curriculum unit on force and the laws of motion, that there were some special oppositions between common sense and the scientific point of view. When a child pushes on the desk with his hand, for example, he identifies the exertion of force with the activity of his own muscles. The scientific point of view requires the idea of force as an interaction between two objects—here the desk and the hand. This kind of difficulty—what might be called a habit of referring all events to oneself or to a person as a cause—clearly had special significance, and Karplus uses it both for the analysis of difficulties in acquiring other concepts and in describing the overall aims of science teaching.

---

[1] Robert Karplus. "One Physicist Looks at Science Education." Prepared for the 8th ASCD Curriculum Research Institute, April 1963; and Robert. "Meet Mr. O." Science Curriculum Improvement Study, March 1963.

How Can We Specify The Initial State *A*?

A child brings responses and skills to the classroom. He speaks his language, partakes of his society, and handles himself and the physical world. Some of these facets of state *A* set limits on what we can achieve as state *B*, and others are the skills and knowledge on which learning is built.

In an ideal state of knowledge, we could use the same descriptive terms and behavioral indices for both states *A* and *B*. The curriculum-oriented approach first analyzes state *B*, then looks back to see what matching or conflicting response tendencies the child has in his repertory in state *A*. This is what both Suppes and Restle do in their analyses of mathematical thinking. The child-oriented approach looks as freshly as it can at the intrinsic order of state *A*. This is how Levin does his analysis of reading,[2] and he gives us a sharper realization of what an extraordinary skill the child brings to us in his control of speech: The child can produce and perceive, in context, all (or almost all) of the significant sound contrasts in the language; he can disregard dialect variations and non-significant voice qualities; he has control over an elaborate implicit grammar; and he has an extensive vocabulary.

In terms of our two major examples—reading and arithmetic—the child can count on his fingers and enumerate objects. He has put things into piles and separated them. He may have a motor pattern for enumerating small objects, and may use a number array (Ghanaian children use counting stones as a device to complete simple arithmetic problems). What is more, the child may sense some correspondences between these various sets (of numbers, objects, positions, and counting acts); it is on these correspondences that the teacher will build elementary arithmetic. Similarly, the child speaks his own language and to some extent has a system of phoneme-classes, sound discriminations and contrasts, the rules of formation and chaining in forming words and phrases, and higher-order structures. He also has or will form visual discriminations among graphemes, allowable distortions of letters, and may become familiar with the usual or allowable combinations of letters. At some point the teacher must establish, or at least encourage, a perception by the child of the correspondence between the auditory-vocal and written-visual symbol systems.

---

[2] See paper following this report.

How Can We Specify State *B*?

What is it we ask the child to do, and what does he do, in school: When the child reads, works out the problem $2 + \times = 5$, or, in a larger framework, when he sees the similarities between someone else's behavior and his own, or when we want him to make discriminations between Rickettsia and viruses, between the styles of James and Beerbohm? When he look at these tasks as separate subject-matters, it is difficult to see that they are similar. We suggest that a detailed analysis of such tasks may reveal similarities, and instruction may take advantage of such underlying similarities.

Our specification of the aimed-for state *B* can be in the following terms.

Information in Memory

This is information that the child does not have to reconstruct or discover again. It may be very simple in form—basic facts of addition, shapes of letters, knowing that Rome is the capital of Italy; it may be more complex like the rules of chess or the rules for declension in French. To get information into memory, the instructional methods of exploring and discovering are probably inadequate, whereas drill and overlearning are appropriate. We might then ask how much information needs to be in memory. In mathematics, for instance, new curriculums put far less in memory than did standard curriculums; in general there seems to be the feeling that older styles of teaching concentrated too much on automatic access in every subject matter. There is also the contrary feeling that we may end up with children who understand the nature of mathematics without being able to use it, or who understand the rules of chess without being able to play it.

How much and what needs to be readily available? In part it depends on what we want the ready availability for. The need is obvious in any kind of speech: we cannot wait while a speaker runs through "der, dem, des," etc., before every masculine noun. Automatic access may make it possible to chain together a longer series of steps, as in Restle's example of the child who tries to rush through a long sequence before the whole shaky framework falls apart. It may help a child use a rule effectively. Reading for meaning, for instance, is difficult when you are still trying to decipher the words.

Precise Versus Approximate Memory

Our goal may be either errorless reproduction of a particular response, as in spelling, or a less exact answer, such as, Sydney is on the eastern coast of Australia rather than the western. Emphasis on the need to introduce approximations comes from the mathematicians, who say that estimating is a sufficiently valuable technique to warrant special training. Now we must ask, what information needs to be known precisely? How much time does it take to learn estimation? Could this time profitably be used doing something else? What does the child need the approximations for? They may be all that the task requires. Approximations may be useful when the child must try out a variety of solutions, or foresee the consequences of several ways of grouping data. Approximations of this kind require considerable knowledge and may be almost as difficult as the full-scale procedure. And finally, what we are accustomed to call "estimating" or "approximating" may lead the learner to higher order groupings. To be able to say "the answer will be somewhere between five and ten" calls for numbers in terms of "less than" and "more than," and permits the child to handle problems to which no *specific* answer can be given. In a similar way, placing an event as "around 1850" may call for more reasoning than remembering a specific date.

The Kind of Response

The teacher may demand recognition vs. production, or answers alone vs. answers with reasons. He may require that the child be able to switch from one response mode to another. There are two contexts in which these differences become critical:

1. One is the extent to which the various modes conflict with one another, or, on the other hand, serve to strengthen grasp of a principle. A constant demand for answers with reasons, for example, would certainly cut down on the flow of answers. At some point, however, giving reasons is a demanded activity and provides a fresh look at the learner's grasp of a rule. Where is this point?

2. The other is in the interrelation between the mode in training and the mode in testing, which are not always the same. Modes of testing are often not in line with the aims we give for state *B*.

A Network or Chaining of Skills

This may be a sequence of steps in a long calculation, or a series of topics in a general curriculum. The aim of calculus before the end of high school, for example, involves a preliminary sequence of steps back to first grade. Teaching a second language involves an interrelation of the aims of correct and fluent spoken use, correct and ready written use, and rapid reading. The question here is the interrelation of parts of the chain, with the most clearcut danger being that, in teaching one, we may make it difficult to teach another later. If the child first sees a second language in written form, he may be hindered from acquiring a correct accent.

Some tasks are difficult primarily because a long chain of behavior must be organized, as in activating a radar set. A chained task may be made easier by several methods:

1. Correct a difficult step. For example, Step 5 may be, "Read dial Q and if it lies between 100 and 110, continue. Otherwise, go back to step 3." With a poor dial, as below, this step may be difficult and may disrupt the whole chain. The whole task may be made easier if the dial face turns green when between 100 and 110.

2. Parts of the chain of behavior may be organized into subchains, such as, "Set all ten switches above the main console in the 'on' position." Such a subchain may function as a unit, if these steps can be done all in order, and this may simplify and make easier the whole procedure.

3. An overall organizing structure may be used to interrelate the parts of the task. For example, a repairman shows sure confidence in activating the set, and can withstand interruption better than the operator. The repairman knows how activation procedures affect the equipment and understands "why" the procedure is necessary.

Making Appropriate Groupings

This kind of task we are most familiar with as a variety of concept formation, demanded in the classroom (grouping agrarian societies, types of revolution, any body of examples for a rule) and in the laboratory (grouping insects together, or metals). History and social studies, for instance, provide examples of groupings in which the instances vary from one another in many ways, and the desired grouping is based on cues that the child is not likely to try first. There are many irrelevant cues or possible bases for sorting, and the child's grouping is more likely to be based on thematic, purposive, or affective cues than on scientific ones.

In cases like these, we can decrease the irrelevant cues and variations in the instances (essentially stripping them down); we can emphasize the relevant basis for sorting (either by verbal or visual emphasis); we can increase the difference to be discriminated (juxtaposing a desert area with a rain forest, for instance). All of these methods help. How much each will help depends on how large a change in the problem is made, and the degree to which the method fits the source of difficulty in the problem. With laboratory materials, we can readily think about how to ring such changes.[3] It would be of value to use the same analysis and equivalent ways of removing difficulties, with materials from fields such as history, geography, or social studies. What instruction makes it possible to group by types such events as revolutions, economic depressions, swings from isolationism? How can we present instances in such a way that the child solves the task? [4]

Less familiar as a grouping problem are the smaller units of material that go to make up the small steps in a chain. It is not immediately apparent, for example, that the bracketing in the arithmetic problem $5 + 3 = X$ is also a grouping problem, and a provocative one. $5 + 3 = X$ demands a grouping of $(5 + 3)$ as distinct from X, and the child who makes perceptually or otherwise the grouping $5 + (3 = X)$ is likely to end with the answer that $X = 3$. This is particularly likely to be a difficulty if the format of the problem suggests a grouping that runs counter to a child's perceptual habits or searching habits. When we present $\underline{\quad} + 2 = 5$, for example, the child frequently sees the grouping as a 5, a 2, and a +, and gives the answer 7. He makes this mistake more easily than when the problem is presented as $5 = \underline{\quad} + 2$. The appropriateness of grouping becomes even more pronounced when we have such problems as $5 + x + 2 = 1 + 8$ or $x + 3 + 2 + 4 + 1 + 5 = 4 + 5 + 1 + 6 + 2 + 3$. How should one teach appropriate techniques of grouping or simplifying? In canceling, grouping by equivalences has to combine stimuli that are visually far apart. The child must scan for equivalences in a way that is appropriate to the subject matter, and a case like canceling in arithmetic becomes comparable to seeing the similarity or identity of two or more instances. Are events X and Y both examples of a particular sociological regularity? Could this medical condition be classed as virus-caused?

Forming Links or Correspondences Between Two Sets of Data or Experience

Often the child is to make links between two sets of data. In reading, he must learn to make links between the written letter and the spoken sound. In arithmetic, we want him to make links between a list of number names and sets of objects; in elementary science, between the balance in the classroom and the seesaw in the playground. In social studies, we would be unhappy if the child's knowledge of his own society and of Eskimo society ran completely parallel, or if he saw no connection between what happens in school and outside school. In a sense, establishing correspondences or links between two or more series, areas of experience, or sets of data is frequently what we mean by transfer. An approach in terms of correspondences or of complete and partial isomorphisms between two sets of phenomena gives us essentially a new level on an old question. We can ask in a different way:

---

[3] *Cf.* T. Trabasso, "Stimulus Emphasis and All-or-None Learning in Concept Formation." *Journal of Experimental Psychology*, 1963, 65, 398–406.

[4] Many of the references to social studies material in this and later sections are based on Lawrence Metcalf, "Research on Teaching the Social Studies." In N. L. Gage (Ed.). *Handbook of Research in Teaching*. Chicago: Rand McNally, 1963.

What are the conditions that make it difficult to establish a correspondence? Are these a function of the degree of ordering for the kinds of structures imposed on the two sets? How can we specify kinds of ordering or structures or degrees and kinds of correspondence?

Where is the most effective place to hook the two sets together? What is the point that would most easily allow the child to proceed by himself and hook the two sets together in many other places? In part, this would be a function of the kinds of structures or relationships that each set had; in part, it would depend on why we want the child to achieve correspondence. We may want him to reach a point where he can readily walk back and forth from one set of experiences or data to another, no matter where he is in the system. Or we may be satisfied with a single correspondence, one that is sufficient to give him a new way of looking at a problem. One of the functions of literature, for example, is to provide an experience or an event "out there" that may be easier to work with than an unformulated personal problem. One such hook, even if the analogy is a poor one, may be all the child needs to get started on the task and see different implications.

Suppose we started with the question of specifying the kinds of correspondence that exist between two sets such as the set of graphemes (the written letters) and the set of phonemes (the spoken sounds). This is the kind of analysis that Levin suggests for reading.

Since the writing system is a notational system for the spoken language, there are obvious relationships among them. (It might be mentioned that it is an impoverished notational system since it does not preserve intonation, stress, contour, etc., with the possible exception of periods, question marks, and commas.) The constraints which appear in the spoken language are also likely to appear in the spelling system. There is no *km* sound in English; so the letters do not appear in the same syllable.

What are the theoretically possible correspondences?

1. One-to-one correspondence between the elements in the written and spoken languages.
2. Complete correspondence (isomorphism?) except that the units in one are different in size from the units in another. Examples: /ca/, the value of the grapheme /c/ is given as /k/ not /s/ by the succeeding /a/.
3. Incomplete isomorphism. The same units in the two always map on a one-to-one basis; others do not. Consider the case of the consonants *p*, *m*, *n*, *p*, compared to the *c*, *g*, and the vowels.
4. For those items which do not show isomorphism, two possibilities exist:
    a. A grapheme maps to more than one sound: c /k/, a, /æ/, /ei/.
    b. A sound maps to more than one grapheme (or grapheme group: /ow/ *ow*, as in how; *ough*, as in plough, *an*, as in Hansa.
5. Cues for decoding writing to sound may reside at various levels (in general, the longer the unit, the more isomorphic are the two systems).
    a. The single letter; these are the invariant correspondences.
    b. Letter and its immediate environment: *ca* vs. *ce*.
    c. Letter and more remote environment: the value for *a* in mate; *e* in deny compared to den.
    d. Syllable: milkmaid (note the impossible single syllable *km*)
    e. Word: *ou* and *gh* clusters in tough vs. though.
    f. Word groups: I read; I have read.
    g. Sentences: (this may hold true only for the stress phonemes): "I will deliver this letter to the White House," said the courier.
    "I will deliver this letter to the White House," said the postman.

This analysis of the language is pre-psychological in that it tells us something about the stimulus and response systems but does not tell us about optimal stimulus displays. One kind of structure or principle of ordering may lead a child into difficulties, if the two principles of ordering in two related sets are different. The temporal order of numbers becomes somewhat irreversible and inflexible —difficult to jump back and forth in—and so does a chronological series of historical events. A serial chant of presidents or English kings is no different from a chant of number names. This difficulty becomes compounded when the principles of ordering are different in the two sets—one organized in chronological terms and the other in more spatial terms (e.g., history and geography) or one referred to principles of evidence, questions of truth, and mechanistic causality and the other referred to beliefs, values, and purposive or affective explanations. This is often the case when social studies and science proceed along parallel lines. In effect, some of the approaches to social studies are attempts to show that the same kinds of explanation or methods of inquiry are relevant to the two sets. Hempel's approach to history is one such attempt. Another is Griffin's way of examining such widely believed and closed-question statements as "America was discovered by Columbus in 1492."

Griffin's example brings us to the second question: Where is the most effective point to throw a hook between two sets? With laboratory materials, it is easy to think of tasks where one hook then allows the child to run off a series of correspondences. Where do we make the most effective link for beliefs? If we want the child to adopt a more tolerant attitude toward a variety of beliefs or to start on an examination of the evidence for a variety of social or historical assertions, which belief or assertion would be the best to have him start examining? To answer this question we need to know the structure of beliefs, their hierarchical order, the evidence supporting each, their certainty, their dependence on authority, and so forth.[5]

Transcurricular Skills or Attitudes

These are often stated in very general value-terms: courage, initiative, judgment, etc. Both because they are so general and because they are in the same class as words like "mother, God, or country," such terms are difficult to work with. They can, however, be made more workable. In general, what we want the child to do is:

—to get started on a problem, to make a try at it;
—to keep working on it, ideally as effectively as possible;
—to know when to stop, either completely or at any step for checking and back-tracking.

In terms such as these, initiative is predominantly conceived with step 2; courage perhaps with step 1, and judgment with step 3. The new terms are still rather unwieldly, but they do bring us a little closer to questions about what the source of difficulty is in steps 1, 2, or 3, and what the instructional techniques are that we may use to remove them.

One could proceed by making a list of values, translating them into behavioral terms, and suggesting an instructional device for each. We have taken a different approach—a closer look at some intellectual skills that cut across curriculums, in particular the skill of coding, and at one particular question: Can coding be trained?

---

[5] Cf. M. Rokeach, *The Open and Closed Mind.* New York: Basic Books, 1960.

Comprehension of speech that functions referentially (Skinner's "tacts") or imperatively (Skinner's "mands") is manifest in pointing, and other non-verbal performances. However, most speech does not call for any such responses. Even when it does, the speaker may not be in a position to observe them. (A gas station attendant could give out-of-town motorists directions for getting to Wellesley for many years and never learn that each one has taken the wrong turn at the cloverleaf.) Children initially penetrate the semantic system of their first language with tacts and mands, but later operate with expansions and recodings and other kinds of feedback. The coding course would work with tacts and mands more elaborate than those from which children take off, on the assumption that this base could be broader and firmer than it now is.

Imagine a student in a room with an individual tutor. The tutor executes some kind of complex performance while the student watches. The tutor might operate a piece of machinery or carry out a demonstration in chemistry or run a toy car along a particular route or use puppets to enact a scene. The tutor speaks not at all but only performs. The performance is repeated until the student thinks he is able to duplicate it. The student, without speaking, attempts the duplication. When the student's duplication satisfies the tutor, the student is ready to be tested for coding skill. If we were using Task *B* to evaluate the coding accomplishments of individual students, we should want to start them all from some criterion level of nonverbal performance.

Another adult, the decoder, now replaces the tutor and the student's job is to tell the decoder how to duplicate the original performance. To evaluate individual coding powers the study should control for the ability and familiarity of the decoder, and should use messages all of which have approximately equal probability. The adult decoder would be allowed to write down the student's exact words so that the effectiveness of the message would not be dependent on the memory of the decoder. The student's success is measured by the success of the decoder in repeating the act or, eventually, a more objective index of adequacy of the verbal message. It would be an objective of the coding course to increase student skill in tasks of this kind.

A few variations on the task above will suggest additional dimension of coding skill. The decoder could be changed from an adult familiar with the apparatus involved to one not familiar with the apparatus. The decoder could be an adult from another country with little knowledge of English or the decoder could be a child. The accomplished encoder would be able appropriately to transform his directions. Coding skill might be still more optimistically conceived. The encoder must transform his directions so as to express different attitudes toward the decoder and the test of his success would be the decoder's reading of the attitudes.

There are three general ways of working toward the attainment of coding skills.

1. Practice with contrived stimulus materials devised to reveal the problems that arise in communication. It might be effective for students to work as laboratory pairs in coding or possibly as teams of two playing against other teams. An effective way to learn the encoding role for any kind of problem would be to have experience of the decoding role on the same kind of problem and vice versa. It would be instructive to reshuffle laboratory pairs from time to time to expose the understanding that develops out of continuing communication and the abbreviation of coding thereby made possible.
2. There should be explicit formulation of the principles the coding games embody. There would be such statements as: "What you have to say in order to communicate idea *A* varies with the set of ideas from which *A* is to be distinguished." This principle could be demonstrated by requiring that a particular red square be distinctively encoded in (a) an array of variously colored circles; (b) an array of variously colored squares; (c) an array of red squares varying somewhat in precise hue; (d) an array of identical red squares variously located. The principles that can be stated are not powerful enough actually to produce the skills in question. However, they will add intellectual interest to the course, and explicit formulations may help to make this early experience retrievable by later advanced studies in psychology or communication of composition.
3. Message content for coding exercises should be drawn from all parts of the school curriculum. Students should be asked to explain to one another ideas from other courses, from science, mathematics, art, and music. The ideal here is that the student who "has had" the principle of the balance beam in class or the law of floating bodies or the principles of visual perspective should try explaining what he knows to students who have not studied these matters. The understanding of the decoders would be tested by some performance other than recitation of the words used in explanation. This might mean setting up balanced combinations on a beam or predicting what objects will float or drawing railroad tracks receding into the distance or expanding and rephrasing the original explanations.

It is reasonable to expect that exercises of the kinds described above would develop coding skills having some generality. However, there is no set of exercises that can equip a student to do precision coding in every domain of meaning for every sort of English-speaking community. The most accomplished student the course could produce would have a great many misunderstandings in his future. There is something that could help him to cope with these misunderstandings: the habit of signaling incomprehension when he fails as a decoder and the habit, as encoder, of attending to and eliciting signals of incomprehension.

The argument for a coding course begins with the claim that good feedback is not often supplied in ordinary discourse. The argument goes on to propose two things that a course might do to improve upon this state of affairs: (1) contrive situations that provide good feedback and see whether general coding skills can be improved; (2) by analysis, example, role-playing, exhortation, and social revolution increase the amount of feedback sought and given in the classroom and outside.

It is possible to conceive of a coding course appropriate to any school year, but these suggestions refer to about the sixth- or seventh-grade level.

What Are the Sources of Difficulty?

If it were possible to give a full psychological account of states *A* and *B*, a comparison of these should be enough to reveal the nature of the difficulties involved in transition from one of them to the other. But it should also be possible to move in the other direction—that is, from knowledge of the difficulties towards (a) an account of the characteristics of state *A* and (b) an understanding of how to effect the desired changes in the direction of *B*.

There have been a number of attempts at direct study of the difficulties which subjects encounter in learning and problem-solving situations. McGuire[6] studied paired-associates learning. His method was (1) to make a logical analysis of difficulties, (2) to relate each of these logically to different types of wrong response, (3) to observe the frequencies of the different wrong responses and to make inferences about the difficulties subjects had in fact encountered, and (4) to test the correctness of these inferences by systematically varying a specific source of difficulty, and requiring that this alter the frequency of just the corresponding wrong responses.

To illustrate, one postulated source of error was confusion of one stimulus with another. The hypothesis that this is a major source of error for any given subjects may be checked by varying the magnitude of the differences between stimuli without varying any of the other conditions. As these differences become greater, stimulus confusion errors should become less frequent, and nothing else should change.

---

[6] W. J. McGuire. "A Multiprocess Model for Paired-Associate Learning." *Journal of Experimental Psychology* 62:335–347.

This provision of a check on the correctness of inferences from products of thinking (in this case, observable wrong responses) to processes (in this case, encountered difficulties) by means of systematic stimulus control is a very important safeguard. Without such a check, it would be possible for the logical analysis to lead one seriously astray.

However, a disadvantage of the McGuire procedure is that if the logical analysis with which one begins should prove to be very wide of the psychological mark—and there is a special risk that this will be so if the subjects are children—the procedure may be very wasteful. It is this kind of consideration which has led Donaldson (1963) to advocate—and attempt—close and detailed observation of the behavior of individual subjects as a way of arriving at hypotheses about the nature of the difficulties encountered.[7]

An example from her work can be used to illustrate the risk that logical analysis will not always lead readily to an understanding of what goes wrong. Take problems of the type:

$B > C$ $A > B$ Which is greatest?

Hunter studies errors in these problems, starting with a logical analysis of the task. But it did not occur to him to consider the possibility that a subject might treat the problem as having 4 instead of 3 terms—that is, might assume that "two *B*'s" were involved —and it is easy to see how logical analysis might fail to give rise to the suggestion that this would occur in children's thinking. Yet Donaldson's observations of individual children led rapidly to the notion that the failure to treat the two separate references to *B* as references to the same term was a common source of difficulty; and, further, that similar difficulties occurred in other problems.

What Are the "Best Ways" To Remove a Source of Difficulty?

We have mentioned in the course of previous sections some specific difficulties and some possible ways of surmounting them—difficulties in establishing correspondences, for example, or in making groupings and discriminations. At this point, we wish to raise some general issues and to draw together some questions about techniques that seem to us to be fruitful areas for research.

One of the general issues concerns "incidental" as against "directed" learning—incidental meaning that the learning occurs without an explicit direction from a teacher or oneself that this material is to be learned. There is frequently, especially in the humanities, the assumption that this kind of learning—often spoken of as intuitive or affective learning—has advantages over directed learning: We can remember still a book read in our childhood or during some particular summer but have no recollection of books studied in college. It is an easy next step to think of incidental and directed learning then as two opposed forms, probably following different laws. In fact, however, these long-term remembrances do follow the same laws as directed learning. They are "happy accidents" or happy combinations of all the things we aim at in good directed teaching; they are not given the label of "learn and forget after examinations"; and they are an unusually good fit with the individual child's interests at that time with his own way of organizing experience, his satisfaction in finding things out for himself, etc. In a classroom situation, we are seldom able to plan for such uniquely good fits. We can, however, and good teachers usually do, provide for some degree of freedom in reading or exploring so that we can maximize the chances of a good fit occurring.

---

[7] M. Donaldson. *A Study of Children's Thinking*. London: Tavistock, 1963.

The other general issue centers around the assumption that the best way to teach *B* is through *B*—an assumption analogous to the wholeword method. There is a major danger in this assumption: We are likely to make it and act on it without a proper analysis of *B* or of ways of optimizing the training program.

The need for a careful analysis of *B* is a point that has recently been made by Gagné.[8] He starts with the prevalent belief that improvement in the technique of inquiry depends on practice in inquiry, and with the prevalent practice of starting students on pieces of research early in their careers. Such practice, he argues, meets only a part of the requirements of state *B*. We do indeed want students to have some facility in carrying out research, but we also want them to cite one other requirement, to be able to distinguish between a trivial and a significant problem. This requirement demands a body of organized and critical knowledge—something we may have left the student less and less time to acquire.

What is likely to happen if we similarly stop short in our analysis of the training program, the techniques we use to achieve state *B?* You wish to teach task *B*, but *B* is hard to learn and the child does not progress. The natural reaction is to shift to something else, some task *A* that will provide a different and better route to *B*. Problems like $5 + x = 8$, $x + 3 = 5$, etc., may present difficulties in first or second grades. The teacher shifts to a problem that seems very similar but is easier: $x = 3 + 6$, $x = 5 + 2$, etc., until the child "develops a proficiency." Then the teacher returns to the first task and finds that the child still cannot solve $5 + x = 8$. At this point, it is easy to think that perhaps *B* was the best training for *B*, after all, and it would not be difficult to find support for the idea in psychological theory.

---

[8] Robert M. Gagne. "The Acquisition of Knowledge." *Psychological Review* 69: 355–365.

This decision is often made, however, without a careful analysis of what we are trying to achieve. We may look only at how well the child does when he shifts to *B*, without regard for the cost in terms of time or errors in learning task *A* as well as task *B*. If *A* is very easy, for example, then its reduced cost may compensate for incomplete transfer to task *B*, and the cost of the overall program may be less than if we used a task *A* which took longer to learn but gave a better performance when the shift to *B* was made.

To specify an optimal program of instruction is complex. There may be several forms of the criterion, and there will usually be a host of possible ways to change the course. One common problem, however, is the sequence of materials. No generally valid principles of sequencing are known, but an analysis of two examples may show what some of the issues are.

Consider the sequence of mastery levels comparing:

Procedure A: High mastery of one context before moving to the next.
Procedure B: Low mastery and planned consolidation later.

Suppose we plan to begin a first course in Russian by training the student on consonant and vowel phoneme discriminations. We begin with minimal pairs of consonant phonemes (e.g., pa-ba) and then move to recognizing allophones of the various vowel phonemes. In this case, where the recognition of vowel allophones does not strongly depend on discriminating consonant phonemes, it seems inefficient to impose a high mastery criterion on discriminating minimal pairs of consonant phonemes before providing some training on recognizing vowel allophones. The effects of forgetting will be reduced by mixing the two types of recognition, and the learning of later, more complex language tasks is benefited by learning consonant and vowel recognition in close conjunction. There are empirical findings to support this latter claim, although providing a general analysis of the causal factors producing these results seems to be an open research problem.

High mastery at one level seems to be an important ingredient of satisfactory progress at the next level. For example, skills in addition help the child acquire skill in multiplication. It is not so clear that mastery of addition should come before subtraction. Some of the newer primary grade curriculums in mathematics introduce subtraction as the inverse of addition, almost as soon as addition itself is introduced. There are sound arguments based on wide experience to support both methods. What is lacking at present, when the curriculum builders are faced with such decisions, is a sufficiently detailed behavioral analysis of the learning involved.

Sequence of Rules and Instances

There are several possible procedures we can compare:

Procedure A: Few instances lead to rule which leads to variety of instances.
Procedure B: Variety of instances leads to rule which leads to more instances.
Procedure C: Rule leads to instances.
Procedure D: Instances without explicit statement of rule.

These procedures can meaningfully be compared only in the light of the nature of the rule and of the relationship between rules and instances in a particular subject matter. Consider the problem of presenting rules, regularities or instances in two areas: elementary science and social studies. In one elementary science unit we want children to learn the principle that there are two ways of making things balance: by varying the position or number of objects on a symmetrical balance (as in a balance beam) or by varying the lengths of the two arms to give an asymmetrical balance. This kind of regularity the child can discover for himself. The main question is how to present the illustrative material that leads him to discover the principle. When we present a balance beam on a table, for example, some observers have noted that few children disturb the symmetry of the balance even when it can be done. Somehow the visual appearance of the material sets up unnecessary constraints. When a walking board (a plank set on a fulcrum) is used, however, and the objects being balanced are the children themselves, the idea of asymmetry (shoving the plank along so that the two sides are unequal) seems to occur more readily. The child can discover the rule himself, but the sequence of instances must be controlled skillfully by the teacher.

In contrast, the rules or regularities in social studies are much harder for the child to discover by himself. One regularity that has been suggested is that all societies have to cope with the common problem of finding food, but the ways in which they do it vary and one of the main determinants of the way they do it is the kind of land they live on. This may seem simple-minded regularity to us, but it would be extraordinarily difficult for the child to find for himself. It is, for one thing, difficult to verbalize and, for another, the instances we would have to present to illustrate it would normally contain so many other tempting points of similarity and contrast that the child would have a great deal of underbrush to wade through on his way to the generalization. In a case like this we would, it seems, be better off stating the principle for the child at the beginning, then presenting the instances, and leaving it for him to figure out for himself what the form of the food-gathering was likely to be in the varying circumstances. The course also teaches about other determinants (e.g., the state of knowledge or technical development, beliefs, etc.). It is probably not wise to state all of the principles before presenting instances, for the number of variables is large and the words have little content for the child. A mixed sequence of rules and instances seems necessary, and the best structure depends on the concrete state *B* to be reached.

THE PSYCHOLOGY OF READING

Harry Levin

Breaking the Code

The ability to read well (whatever that may mean) is the most fundamental and broadly useful transcurricular skill. A most pessimistic observation is that this truism is never gainsaid and has received obeisance in some 12,000 published researchers and polemics during the past half-century. Nevertheless, and only partially to justify our own concern, we must aver that the process of learning to read and of reading is not well understood. There are a number of reasons for this. To my mind, the "wheel-spinning" characteristics of reading research have resulted from the concern with individual differences in the performance of this skill to the exclusion of the study of the nature of the process itself. That is, the empirical paradigm has been to compare "good" and "poor" readers, selected by some global, nonanalytic criterion, rather than to dissect the process itself. It is the prejudice of this discourse that fruitful hypotheses and findings will come only from an analysis of the acts of reading.

I do not want to deny the eventual usefulness of the appraisal of differences in reading ability but only to assert that this approach waits on solutions to questions (to take one example) about sequences of stimulus presentations as they relate to learning something about reading. (I am deliberately being vague at this point about what reading and its component parts are, which is the real problem of this paper.) Suppose, in an ideal world, that certain stimulus display sequences control reading skill for all children. The individual differences problem evaporates. In this less than ideal world there will probably still exist variations after all reasonable stimulus display variations have been exhausted, and it is at this point that individual difference variables—e.g., intelligence, motivation, attitudes—should be introduced. This is, of course, an assertion about research strategy which I cannot justify by any objective criterion except its fruitfulness. Still, it seems to me reasonable that we place our first bets on variables which are under the control of the tutor rather than those in the hands of God.

Let me tell several anecdotes that lead me to emphasize the nature of the task over the differences among children. In Italy, I queried first-grade teachers about their teaching children to read. They averred, and I know it was true, that after 3 months *all* children could read anything presented to them. I wrote some nonsense materials following the rules for Italian spelling, and every child in the group that I called on could "read" the paralogs. Why the consistency across children? To answer this, I have another little story about my son, who reads English poorly. One afternoon when we were exploring Rome, we passed a building with the huge sign *Ministero di Telecommunicazione.* My son read it off, with proper stress and intonation, incidentally. When I reminded him that he would not have tried an English legend so long and complicated he said, "Yes, but it always works in Italian."

These incidents convince me that the first step in analyzing reading is to pay attention to the code: the correspondences between the written symbol and the sound which it signals. Admittedly, the code in English is more difficult than the Italian one so that the variations among children in learning it is what we have come to expect in mastering any difficult task. Further, we have learned in other similar domains in psychology to concentrate on ways of reducing the difficulty via the task variables.

The Task of Reading

One of the lacks of previous research on reading has been the failure to recognize that many skills are involved. When a standard reading test is used to appraise reading skills, the score may be due to heterogeneous mastery of the heterogeneous components. I do not believe, however, that the score is a grand mean because the skills are arranged in a natural hierarchy. That is, mastery of successive steps is limited by degree of competence in earlier ones. Two broad divisions are evident:

1. Learning of the code. English orthography is an impressive representation of the sounds of the language. A first task is to learn this code. This process will be discussed in detail below.

2. Learning to use the code. This rubric subsumes the primary concern of the educator: reading with meaning. Here, too, the problem of units appears as well as the various contexts and purposes for reading.

These two major processes raise problems vis-à-vis each other, e.g., sequencing, overlearning, etc., that are applicable to each process itself. This repost will follow the sequence of discussing (1) and (2) and finally the relationship between (1) and (2), in all cases following the analytic scheme represented by the outline.

Learning the Code

In theory, we should specify the nature of the task at state *B*, yet in reading there are certain obvious properties of state *A* that seem relevant regardless of the specific state *B* problem. These state *A* conditions are given, to a great extent, by the nature of the English writing system and by the linguistic specification of the spoken language to which the writing system is coordinated.

Let me review the obvious. English is made up of about 40 significant sound contrasts plus a huge variation around these sounds which make little difference in speech perception. Results of research on speech perception by Liberman and his coworkers at the Hawkins Laboratories indicate that the perception of consonant sounds is categorical; that is, dimensional acoustical variations on a consonant sound are perceived as belonging to either one or the other category with a sharp break between the categories. Discrimination among variations on a vowel sound, however, follows the fine gradations of the physical stimulus. This leads us to the most important characteristics of state *A*:

1. The child who starts to learn to read has a fantastically elaborate mastery of his spoken language.
   a. He is able to produce and to perceive in context all (or almost all) of the significant sound contrasts in the language. This skill includes the disregard of the noise in the phonological system, e.g., ignoring nonfunctional voice qualities of the speaker (young vs. old, male vs. female, etc.); he can group allophones, respond to dialect variations as being similar, etc. There is probably a difference in his receptive compared to his productive skills.
   b. He is able to produce and respond to the morphophonemic variations in the system.
   c. He has learned an elaborate functional (implicit) grammar.
   d. He controls perhaps 5,000 words (though I do not know whether this figure refers to his production or reception). By "controls" I think I mean "understands" in the sense that he behaves appropriately when he uses the word or when it is spoken to him.
2. The concept of a writing system. We may wonder if the

child has the general notion of the relationships between writing and speech. Surely, almost every child has been read to. Does he see this as some adult magic? The book may be an incidental prop to story-telling so that children when they tell stories or repeat from memory have a book open in front of them. In my own experience, children are cued to the story by the pictures and can actually get quite good at phasing the story with the appropriate page. Also, surely, every child has learned to make the correct sound in the presence of orthography: STOP, GO, NAME, etc.

This brings me to a far-out notion. I am told that the elementary math curriculum starts by making the subsequent materials "meaningful" in the sense that the children are taught why they are learning mathematics—or the nature and semantics of the symbol system. I would suggest that reading be introduced by teaching the nature of the writing systems. Certain games that may intrigue children are obvious: making up a morphemic writing system, artificial language, coordinations, one-to-one correspondences, correspondences based on contingencies, etc.

3. The perception of letter and word forms. I think that too much has been made of this source of difficulty in reading. Gibson's research indicates that there is little confusion among letters except for some obvious instances: O vs. Q. A master's thesis under my direction by Goe Edelman indicates that the lowest source of error in grouping word forms as similar is overall outline or shape. The major sources of error, incidentally, are the instances where two words share the initial letter.
4. There are a variety of other predisposing postures which sometimes are lumped under reading readiness training. Some are specific to reading: going from left to right. Others are general to many learnings, such as listening, attending visually, following instructions, etc.

Notice that in terms of our outline we can go a long way toward specifying the characteristics of state *A* before specifying state *B*. There are levels of generality here. If the child has learned previous materials, they may specifically influence state *B* and their relevance must be appraised in terms of the *B* task. In reading, there are certain generalities of *B*, as the nature of writing systems, which are nonspecifically relevant, to coin a term. However, these relevancies are in terms of the materials to be mastered rather than general cognitive skills, which also have nonspecific applicability to the analysis of any *B* state. Do other curriculums also permit some specification of state *A* prior to state *B*?

I have stated many times that the first part of learning to read is to learn the code, the grapheme to phoneme correspondences. Ultimately, the object is to make the access to the code automatic or to make the *code transparent* so that the purposes of the code become primary. This may be an analog to learning algorithms in arithmetic not for themselves but as automatic devices for problem-solving. As I shall suggest below, in reading we have no natural ordering which permits the derivation of the algorithm before its automaticity.

Example 1

The child is presented with the stimulus array *MAT* to which he is to respond orally. We are purposely simplifying the problem. He says it aloud, so that we have a check on his performance. The word is a graphic monosyllable for which the spelling rules are reasonably without exceptions in English. The initial and terminal consonants have single values in the monosyllable. Compare *mat* with *cat* in which, taking only the initial consonant, the grapheme *c* may have the phonemic values of /k/ or /s/.

1. Whole word method. Typically the child may be given a picture of a mat and the word printed below it. He may guess the word or he may be told it by the teacher. The important point is that he has no internal check on the accuracy of his reading. Feedback must come from an outside agent.

What has the child learned when he says "mat" to its graphic representation? He has presumably formed an association between the stimulus and his response. But the stimulus is a complex one. The discriminated parts may be:

a. The total, detailed complex including the internal elements and the outline. Our research indicates that this is not usually the case.
b. One of three individual letters. The research indicates that the first letter is maximally discriminated and "stands for" the whole word. This is tricky especially if a subsequent written word he is to learn begins with *m*.

A bright child may induce from this and other instances the alphabetic principle, although if this were the purpose of presenting whole words the choice of stimuli and instructional techniques would differ.

This is not the place to belabor the reasons for the whole-word vogue. It came from a weird combination of Gestalt theory, exasperation with the irregularities of English spelling, and the presumed motivational benefits of giving the child a rapid reading vocabulary.

In its pure form, the whole word method gives the child no generalizable skills for reading new words.

2. Phonics. Carroll has recently pointed out that phonics has no precise definition in the educational literature but probably means a method for teaching "letter sounds." By phonics, I shall mean teaching the child sounds to associate with given letters: a = ah, b = bah, etc. There are some obvious difficulties here:

   a. Many of the letters have various associated sounds.
   b. There is, in English, no sound like "bah."
   c. Contextual Phonics. For want of better terminology, I shall coin this label. I mean a procedure whereby the word group is analyzed into its constituent sounds; e.g., the teacher makes the children aware that *m* has a value, *a* another, etc.

Advantages:

   a. Maximizes the regularities in English by using cues other than the single letter; e.g., the value of /a/ in mate, compared to mat. (More about this later.)
   b. Preserves the blends between phonic elements—*mat* vs. *muh-ae-tuh.*
   c. Teaches the alphabetic principle.

The major advantage of B and C is that they permit the reading of new words.

Rules and Instances

If we think of the specific grapheme-phoneme associations as instances, then the rule generalizes these instances with greater or less precision. Under certain boundary conditions, the rules are invariant; e.g., many of the consonants in initial positions. Other invariants concern letter groups, such as *qu*, *ca*, *ga*, all in initial positions. From this point, the rules are complicated in various ways: 1) The position of the letter in the word; 2) The environment of the letter in both immediate constituents, as *ca* or more remote cues, as when the terminal vowel is a marker for the quality of the preceding vowel, m*ate*; 3) The syllabification of the word (cf. the conundrum of a four-letter word beginning with *den* which turns out to be *deny*. Finally, we must admit to a huge number of single instances, as the value of *o* in women.

The problem is this: The rule becomes more complicated as it encompasses more cases, or simple rules have too many exceptions. The pedagogical decisions then become:

1. The generalization of rules from a small number of regular instances.

2. The introduction of nonrule instances.
3. The generalization of more complex rules.
4. The introduction of orphans.

There are a variety of research problems here:

1. The sequence of rules and instances.
2. The sequence of various orders of rules.

This problem has, in other forms, received research attention. From linguists, the recommendation has come that the invariant cases be introduced first, followed by nonrule instances. Artificial orthographics are based on this notion. However, the point at which the new instances are introduced and the possibility that they may be considered "orphans" has not been treated. I raise the question of the effect of overlearning the simple rule on the modification of this rule.

3. Questions of the sequencing of instances for contingent and noncontingent rules.
4. How complex should a rule be before its usefulness decreases?
5. Simple rules and exceptions vs. complex rules and few exceptions.
7. Probability statements as rules. This approach is interesting. Suppose that the letter *a* has five possible values: $a_1 = .50$, $a_2 = .20$, $a_3 = .20$, $a_4 = .09$, $a_5 = .01$. Then, a_5 could be taught as rote memory items. Should $a_1 \ldots a_4$ be taught as a sequence so that the child would try them in that order and maximize the probability of success? If we add contingencies, the probability estimates could be made more precise, but might lose their simple usefulness.

The child may discover the rule or induce it from the instances. In an experiment with adults, using invariant rules, Gibson and Bishop found that these subjects who discovered the rules of grapheme-phoneme correspondence performed as well on a transfer task as those who had been explicitly taught the rules.

Correspondences as Algorithms

I am not sure that the concept of algorithms as used in mathematics will apply, but think of this section as an exercise. Assume that the child knows many grapheme-phoneme correspondences. He is given the new word *mat* to read; he has experienced all of the letters in other contexts. How might he apply the rules? The letter *m* gives no difficulty—it is invariant in this position. Likewise *t*. The medial vowel carries problems. Let us say that he starts to run through a sequence of vowel sounds. What are the conditions of the algorithm yielding an inevitably correct end state?

/m/ /ei/ /t/ —mate
/m/ /e/ /t/ —met
/m/ /o/ /t/ —mote
/m/ /a/ /t/ —mot
/m/ /i/ /t/ —mit
/m/ /ae/ /t/ —mat

There are two questions: (1) What is the sequence in which he searches, and (2) What signals the correct end state?

The intuitive model for the end state that I prefer is a matching to memory process. This implies that all forms not in memory storage will be rejected (unfortunately, this means nonsense as well as sensible, unknown items). However, notice in the above example that he hits upon few sensible forms, and he may stop at any of these. He may check his choice by recoding and comparing with the original, so that *met* does not match *mat.* Or, he may go outside of the word to check semantic constraints; that is, he may find that *met* makes no sense and he tries again. However, this last procedure implies facility in the use of the code (reading for meaning).

Matching to auditory memory is vague. The child certainly does not match against his total auditory lexicon. On the basis of whatever cues he can get from the point to which he has decoded the graphic complex, he selects from memory the body of items to be used as models for his utterance. There are some interesting problems here. Suppose the child can decode to the first sound; then he will bring forward all words beginning with *m.* On the other hand, suppose that he decodes the *-at*; he may also hit on *mat* eventually. But the implication is that his memory storage is organized by medial and terminal positions. On second thought, this is not too farfetched, since the left to right sequence and the concept of *word* probably follow rather than precede learning to read.

Rule Selection

After the rules of correspondence have been acquired by the child, how does he use them in decoding orthography to sound? The rules have these characteristics: They vary in the compass of instances which they cover, and they vary in the size of units to which they refer. That is, some rules cover every instance, while others have many exceptions; and some refer to single letters, others to letter groups.

To any instance, more than one rule is usually applicable. The child must choose the relevant rules and decide among them. Each instance should have markers which index the relevant rules. Back to our example, *mat*. Which keys the child most: rules having to do with graphic monosyllables, initial consonants, medial vowels not followed by *e*, etc. The rules may also have a hierarchical arrangement which I think is what I mean by complex rules. Therefore, vowel-consonant clusters of the form *at* have different rules when they appear in monosyllabes or disyllables; viz., m*ate* vs. m*at*ron, vs. m*at*.

Various linguistic and psychological problems appear:

1. We need a more extensive spelling-to-sound mapping in English directed toward showing the regularities (Hockett is doing this).
2. What is the order of application of rules?
3. How mark the instance so that it will correspond to the rule? We might in the early periods of reading use diacritics to signal generalizable and nongeneralizable instances, which may aid in the induction of rules and the later recognition of instances covered by the rule.
4. The explications of the rules. Adult readers operate as though they have rules of spelling to sound correspondence, though these rules are certainly not explicit.

The problem changes drastically when the word is *mate* rather than *mat*. To handle this word, it would be most inefficient for the child to ring all the changes on the vowel /a/ because though he may hit on the appropriate pronunciation, he can have a procedure which will yield high probability of success. The task is to take as a perceptual unit (a–e), where the terminal *e* is a marker for the value of the preceding *a*.

During acquisition of this regularity, we may think of the procedure as a concept formation experiment. The task is to search for the stimulus grouping which gives the middle vowel its characteristic value. When this is discovered, extensive training by some as yet unknown procedure should be carried out to yield a perceptual grouping in these instances. We want the (a–e) to jump out at the child. The present work on units in word perception, so far as I know, is based on groups of successive letters. Yet in this case, the other letters are irrelevant for the first decision about the character of this instance, i.e., what rule is available. A second conjecture about the sequence is: class of monosyllables, terminal /e/, value of initial consonant, vowel, consonant.

Research problems:

1. Most efficient perception training: -a-e or -e, or -ate, or ma-e, or mate. Criterion in terms of generalization to other instances.

2. Perceptual groupings of these instances by experienced readers.
3. Problems of instance to choice of rules.

Response Modes

We may list the response modes either actually used or theoretically possible in teaching grapheme-phoneme correspondences. They are relevant insofar as the child learns different things from the various modes or they permit different analyses of his behavior.

1. Orthography ——> speech.
2. Speech ——> orthography.

The second depends on a procedure in which the teacher writes some verbal production of the child. This might be controlled somewhat by giving the child standard and rationally sequenced items to say. A complete print-out of his free discourse is not technically feasible and may not be desirable except to give the child the notion of the relationships between his spoken language and writing. Suppes' results suggest a wild analogy which permits a choice between 1 and 2. Since the form $x + 3 = 8$ is more difficult for children than $3 + x = 8$, we assume that putting the unknown first is the source of difficulty. Further, if the spoken language is "3" and the orthography "x", the recommended procedure is the second, above. The child learns that his language is represented in writing rather than that writing is represented in his language.

3. Oral stimulus ——> choice among grapheme groups.

This technique permits the translation of minimal language contrasts to their graphic counterparts and perceptual sharpening for the written cues. The ordering of instances may be provided by 1 and 2 and the testing of the applicability of the rules by 3.

4. Oral stimulus ——> writing.

Writing is introduced here simply as another mode of overt behavior by which mastery can be appraised and briar patches located. The acquisition of writing as a skill and its relation to reading is itself an interesting research path which unfortunately will not be followed in this discussion.

5. Visual stimulus ——> silent reading.

Since writing is an inadequate representation of speech, the first training in correspondences makes most evident this connection. We obviously cannot go on for long reading out loud (as I believe some school systems do). There must be practice in the skill as it will be used, and this brings us to the final section of this part of the discussion—the arrangement of circumstances for the automaticity of decoding writing.

From Opacity to Transparency

Teachers often tell me about a magical click that comes around the second grade when the halting decoder starts reading smoothly and rapidly. I don't know whether this is a discontinuous process, and indeed the research on code learning suggests that, though the sequence is a series of backing and fillings, it is continuous. The purpose of concentrating on breaking the code is to phase out attention to the code *qua* code. While the child is attending to "what is that word," he can only peripherally be reading for meaning, pleasure, or inspiration.

Several examples will clarify what I mean by code transparency. When a person is learning a foreign language, he understands imperfectly because he is concentrating on the decoding process rather than on the communication which the code carries. Similarly, composing an utterance in an imperfectly controlled language is tedious and the output simple because the speaker is *consciously* working on the code itself (cf. my paper on inflectional suffixes). Think of how difficult it would be to talk or read our native language if we were conscious of pluralizing, changing tenses, thinking about referents for words, etc.

APPENDIX A

WORKING PAPERS

INFORMATIONAL STRUCTURES

Alfred L. Baldwin

One of the most vexing problems for a teacher is to decide how to present the information to students so that they will understand and profit from it. All of us have had the completely frustrating experience of knowing just what we would like the student to understand, only to find that the presentation of it apparently transmitted no information. The student apparently was unable to grasp the explanation that seemed so clear to us. Some of the intuitive wisdom of teachers is expressed in the advice to "start the explanation where the student is," or to "use concrete examples to illustrate abstract principles," "to clarify the problem before giving the explanation."

Thus it is common in beginning arithmetic to explain the decimal notation system by picturing a set of 16 sticks as "one bundle of 10" and "six separate sticks." The bundle is presented either concretely as an actual bundle or pictured in the book. The child is encouraged to visualize 34 as three bundles, plus four extra. An alternative visualization is to represent the numbers as points on a long line, with the "10," "20," etc. marked in some special way. The number 34 now is described as four steps beyond 30. The two visualizations may both be available to the same student—they are not incompatible in that sense. The point is that the two visualizations are equivalent in some senses, but probably have psychologically different consequences of learning to add. How can the selection of one or another mode of presentation be made a less intuitive judgment, and more an empirically based decision?

The strategy of this paper is based upon the hypothesis that the purpose of instructional material is to change the individual's cognitive structure from one that is inadequate, incomplete, or incorrect into one that is improved. This requires an empirically founded set of hypotheses about the consequence of presenting instructional material with one sort of structure to an individual with a different cognitive structure. Presumably, the relevant variables are the discrepancies between the existing and the presented structure.

If the discrepancies in the two structures are relevant, then it is important to be able to describe cognitive structures in such a way that the discrepancies are revealed clearly. The bulk of this paper will deal with the description of various types of cognitive structures that appear in the course of cognitive development of the child. One section, however, will address itself to the problem of identifying cognitive structures through observation, interview, and experimental testing.

Specifically the following topics will receive attention:

1. How can a cognitive structure be described and classified so that its relevant properties are revealed?
2. How can these various types of structures be identified through behavioral observation or experimentation?
3. What hypotheses have we about the relationship between an existing cognitive structure and the structure of the presented material, for optimizing the change in cognitive structure?

Distinction between Cognitive and Non-Cognitive Behavior Mechanism

Cognition in the rather narrow sense that we propose to use it in this discussion is a representation of some segment of reality. It may be a picture, a description, a map, or it may take any of a variety of forms; but it is a representation of something else besides itself. Its essential property is how well it represents whatever it represents.

Not all behavioral mechanisms are representations. A conditioned response in one of Pavlov's dogs need not be a representation of the bell, the food, salivation, or of the relationships among the three. The conditioned response is a property of the organism that permits the bell to cause salivation, but it is not a representation of the action any more than the rigidity and strength of a chisel that transmits the impact of a hammer blow to a piece of soft wood and causes a notch in it are representations of the hammer blow or of the action of chiseling.

This assertion implies, of course, that not all behavior need be cognitively mediated. *A representation of the stimulus and/or the response may be a part of the causal mechanism by which the stimulus elicits the response, but the causal mechanism need not involve cognitive representation.*

The sensori-motor stage of development as it is described by Piaget is intended to describe a set of behavior mechanisms that are not cognitively mediated. The infant—until stage VI—is capable of a variety of adaptive behaviors, but no internal representation either of the stimulus or the action itself is required. Of course, the behavioral mechanism of the infant must be described by scientific psychology, but such a description or theory is not descriptive of the child's cognition.

From the point of view of the infant in the sensori-motor stage, it seems likely that in the appropriate circumstance he does what comes naturally to him, and that as far as he is concerned that is the total picture. Piaget develops the hypothesis that the first sort of cognitive representation is an internalization of the sensori-motor schema. The infant in stage VI is able to pretend and to imitate an action after the model is removed. This suggests that there is some internal representation of the action that exists even when the action is not being performed. Piaget uses the term "image" to describe any such internal representation of a sensori-motor schema.

This suggests one type of cognitive structure that may exist. The individual may have an image of each of a repertoire of responses to situations, the image representing in some way both the action and the circumstances in which it occurs. Perhaps the closest analogy in adult experience is the feeling some people have in tracing down an almost forgotten pathway through a city. "I know the corner where I must turn left—I can't say what there is about it, but I know it."

Distinction between Cognition and Cognitive Structure

When the child holds in mind in some fashion a representation of an action that he is not performing, he is manifesting cognition, but not necessarily a cognitive structure. There are two senses in which the term "cognitive structure" may not be appropriate. On the one hand the imagery of the child may be a sort of isolated event that is unconnected with other images and thoughts the child might have. In this sense there is no structure, since there is no pattern of interrelations among the elements in the child's cognition. Structure implies a set of interrelated elements.

Secondly, the term cognitive structure implies a relatively long-lasting dispositional construct—something that the child knows and which is available when needed. An evanescent image that permits delayed imitation or delayed responses to problems may be the first signs of a permanent cognitive structure, but it hardly qualifies as a cognitive structure any more than an ordinary afterimage or eidetic image.

One function of cognition is "time binding," that is, the integration of events that are temporally separated. This time-binding function is illustrated by the earliest beginnings of imagery, because the image permits delayed imitation, but at that level of development it is not very effective. The time-binding function is more clearly illustrated when the individual, through the use of a cognitive map, plans his actions to take advantage of long-past learnings and to anticipate the future consequences of actions.

The time-binding function requires that in some way entire cognitive structures be activated as a whole. The individual must know not only what he is doing, but also, what the other alternatives are, what his future choices are and, as Piaget emphasizes, how to reverse any contemplated action. This activation can be visualized as a sort of illumination of a structure; in different circumstances different amounts of the cognitive structure are illuminated and thus become effective in controlling behavior.

The cognitive structure must of course be connected in order for anything other than the current thought to be illuminated. Thus we might imagine that the imagery of the infant, once he is capable of imagery at all, is a set of unconnected potential images. The illumination of one of them does not illuminate any others because each image is independent of every other. There is no evidence to suppose that such a condition actually exists in infancy, but it represents a sort of limiting case of minimal organization.

As the child grows older, we hypothesize, a number of changes occur in his cognitive processes. Two such changes have been suggested by the discussion in this section.

1. The units of cognitive structure become interrelated so that true structures may be said to exist.
2. There is an increase in the extent to which the entire structure is illuminated or activated whenever an element of it becomes active in the control of behavior.

Nature of Iconic Representations

Just as the earlier cognitions of children are not well organized, another feature of imagery is that it is in some way a picture or a replica of an action and also of a situation. The purpose of this section and the next one is to explore the meaning of this sort of cognitive representation and to attempt to describe it in a coherent way.

Bruner used the term "iconic" in his introductory paper to describe this pictorial quality of some cognitive representations. The feeling that such cognitions are mere replicas of actual experiences has also led to their being labeled concrete as opposed to more abstract types of cognitive organizations.

A Nomenclature

In order to discuss the characteristics of a pictorial cognitive representation it may be useful to establish a terminology. We will at various times in this paper be talking about an external system of some sort which is to be cognitively represented. Any such system can perhaps be described as taking on a series of *states*. These states can be formally described as sets of values taken on by the parameters of the system, but it is important to realize that a state may be perceptually discriminated from other states, recognized as having occurred before, and even labeled, without being anything more than a unitary undifferentiated event. It may be perceived as unique but not necessarily resolved into a set of values of the various parameters.

These states are related to each other in a functioning system by the fact that one state may change into another in some predictable way. The changes from one state to another will be labeled "transitions." These transitions may occur spontaneously or may result from the impingement of external events. Those external events may be the actions of the individual whose cognitive representation we are describing. We will label those *actions*, meaning actions of the person himself.

If one were building a theory about the functioning system, these states and transitions would represent the empirical data that are to be predicted from some set of assumptions, definitions, and intervening theorems. We will simplify this picture of the theory by saying merely that the assumptions and definitions constitute the "rules" of the system.

An Example of the Analysis of an Iconic Cognitive Representation

In order to have some concrete examples with which to deal, to present some of the problems of describing iconic cognitive structures to illustrate their variety, and also because the study is interesting in its own right, we will digress at this point to describe briefly a research program we are engaged in on people's cognitive picture of interpersonal relations. Specifically we are trying to formalize the "naive theory" of choice behavior.

In the experiment we present the subjects (persons from kindergarten up through college) with a series of situations. Each situation represents a choice made by a hypothetical person whose intention the subject is to judge. There are many ways to describe the kinds of choices people can make, but for this experiment the choices are described in terms of whether or not they benefit the person (P) who is making the judgment and who is the subject in the experiment and whether they benefit the other person (O) who makes the choice or not. Thus one situation is described as $\overset{+}{P}\,\overset{-}{O}/\overset{-}{P}\,\overset{+}{O}$. This is to be read as follows: O had a choice between benefiting P and harming himself or harming P and benefiting himself. He had to choose one or the other. He chose the first alternative (i.e., to benefit P and harm himself, a choice that is indicated by the preferred alternative being presented above the line—i.e., he chose the first over the second). The subject (P) is asked to judge the strength of O's intention toward P; was it hostile or benevolent and how much so?

If we consider O a functioning system, then this choice represents a "transition" from a state where neither P nor O was being benefited or harmed ($\overset{\circ}{P}\ \overset{\circ}{O}$) to a state where P is benefited and O is harmed (P O). Another important feature of the situation is that one and only one other transition existed with $\overset{\circ}{P}\ \overset{\circ}{O}$ as the initial state. That one would have resulted in P's being harmed and O's benefiting (P O).

In the experiment we presented each subject with 16 such choices to judge. They are represented in the table below.

$$\begin{array}{cccc}
\overset{+}{P}\overset{-}{O}/\overset{-}{P}\overset{+}{O} & \overset{+}{P}\overset{-}{O}/\overset{-}{P}\overset{-}{O} & \overset{+}{P}\overset{-}{O}/\overset{+}{P}\overset{+}{O} & \overset{+}{P}\overset{-}{O}/\overset{+}{P}\overset{-}{O} \\
\overset{+}{P}\overset{+}{O}/\overset{-}{P}\overset{+}{O} & \overset{+}{P}\overset{+}{O}/\overset{-}{P}\overset{-}{O} & \overset{+}{P}\overset{+}{O}/\overset{+}{P}\overset{+}{O} & \overset{+}{P}\overset{+}{O}/\overset{+}{P}\overset{-}{O} \\
\overset{-}{P}\overset{-}{O}/\overset{-}{P}\overset{+}{O} & \overset{-}{P}\overset{-}{O}/\overset{-}{P}\overset{-}{O} & \overset{-}{P}\overset{-}{O}/\overset{+}{P}\overset{+}{O} & \overset{-}{P}\overset{-}{O}/\overset{+}{P}\overset{-}{O} \\
\overset{-}{P}\overset{+}{O}/\overset{-}{P}\overset{+}{O} & \overset{-}{P}\overset{+}{O}/\overset{-}{P}\overset{-}{O} & \overset{-}{P}\overset{+}{O}/\overset{+}{P}\overset{+}{O} & \overset{-}{P}\overset{+}{O}/\overset{+}{P}\overset{-}{O}
\end{array}$$

After giving an appropriate explanation of the terminology, we have found that children of all ages from 7 up can intuitively feel their way into these choices and can make judgments about the strength of O's intention in the various situations. The task of the research was to formalize a theory of choice that would predict accurately the judgments of intention made by our subjects.

We called this theory a "naive" theory because we viewed it as a set of tacit assumptions made by naive subjects about the laws of choice behavior. By assuming they were operating on these tacit assumptions, we can predict how P would judge O's choice. By test we found that the assumptions did, in fact, predict P's judgments very well indeed. In addition we asked the subjects to estimate the probability that another person—a stranger—would in fact make each of the choices described. Again the naive theory enables us to predict very accurately P's estimate of the probability of each choice.

The assumptions that make such accurate predictions possible are as follows:

1. If the consequences of two acts *a* and *b* are identical, then the valence of *a* equals the valence of *b*.

2. If the consequences of two acts *a* and *b* are not identical, then the choice as *a*/*b* implies that the valence of *a* is greater than the valence of *b*.

3. If the act a has a number of consequences (x, y, z), then the valence of a is equal to the sum of the valences of the consequences.

4. If a consequence of an act is to benefit the self, then—other consequences being equal—the valence of the act is greater than one that harms the self.

5. If a consequence of an act is that both P and O receive the same ($\overset{+}{\mathrm{P}}\,\overset{+}{\mathrm{O}}$ or $\bar{\mathrm{P}}\,\bar{\mathrm{O}}$) outcome, then—other things being equal—the valence of that act will be greater than one by which P and O receive different outcomes ($\overset{+}{\mathrm{P}}\,\bar{\mathrm{O}}$ or $\bar{\mathrm{P}}\,\overset{+}{\mathrm{O}}$).

Given the fact that this set of assumptions does permit the accurate prediction of P's judgments of O's intention and also P's judgments of the probability of O's choice. (The derivations and predictions are available for distribution to those interested.) The research poses some interesting questions concerning the description of a cognitive structure.

It is appropriate to say that the subjects in this experiment have an iconic cognitive representation which includes the various possible choices O can make, the likelihood of those choices, and the sort of intentions that go along with each choice. It is very unlikely that any sizable group of subjects cognized the "rules" of the system that they dealt with intuitively. These rules are implicit in their intuitive knowledge of the system, but not explicitly represented cognitively.

This experiment seems to illustrate nicely the difference between an iconic and a formal cognitive representation of a system. Our problem is to describe more precisely the differences between the two.

Properties of an Iconic Representation

Two essential properties of an iconic cognitive representation suggest themselves.

1. In the iconic cognitive structure the elements consist of the states of the system, and the relationship between elements consists of the transitions between the states. Given a presentation of a "state" or a "transition" of the system, the individual can make certain judgments about it. He can say that it is possible or impossible, and perhaps also how likely or frequent it is. He can intuitively know what are other features of the state—*i.e.*, in the experiment he can recognize the intention that goes with each transition even though the intention is not part of the presented situation.

2. Each of the states and transitions is represented as an "image" whose properties are "read off of the image." Frequently the image

is visual so the cognitive structure has a pictorial quality, but other cognitive structures may not have this visual character. It may be auditory, as when the musician who plays by ear knows what will "sound right" or when the preschool child follows grammatical rules without knowing them. It may not be clearly sensory at all; that is one of the interesting features of the sorts of interpersonal judgments that we have been studying.

Another and different type of problem involving iconic representation occurs when one considers the variety of iconic representations of the same formal property. These examples are introduced to raise problems and perhaps to force further distinctions among cognitive representations. For example, one of the Piaget experiments is concerned with the relation of three colored beads: a red, a green, and a blue one in a tube. Since the tube is just large enough to fit the beads, their order within the tube remains invariant if the tube is moved around or shaken. The same invariance of order could be achieved in a variety of other ways. A stick could have three painted rings on it: a red one, a green one, and a blue one. The order of the rings would be invariant because of the rigidity and continuity of the stick. Three beads could be threaded on a long string. Again the order of the beads on the string would be invariant. The invariance of the order can be explicitly described by a set of axioms concerning a set of elements with defined relations among them. These are the assumptions of a linear graph in topology, and include such assumptions that if A is between B and C, it is between C and B, and that ABC is equivalent to CBA.

Despite the fact that there is an invariance of order in all of these situations, it seems obvious that the invariant order of the painted rings on the stick is much more readily recognized than the invariant order of the beads on a loose string. Why is this true? It seems tied to the fact that the stick is rigid, that it is an object with a bundle of properties where the topological invariance of the sequence is part and parcel of a Euclidean invariance of relative position in space. That the different parts of a stick do not move around with respect to each other is an inherent property of sticks; it is an external constraint imposed on the beads by the tube. At the same time the constraint on the beads is milder; they can move back and forth in the tube, the distance between one bead and the next can vary. It is only the order that is kept invariant.

We might suppose that the common occurrence of sticks in the human environment, together with the fact that every such occurrence represents the same bundle of properties, gives a stick a set of implicit properties that are manifested in whatever manipulations the stick may be put through in the imagination. The middle of a stick coming out of a tube before either end violates its rigidity and cannot be pictured without violating its "stickness."

Thus it seems from this analysis of this example that the recognition of invariance of order in the case of colored rings on a rigid rod depends upon three factors:

1. The rings on a rod meet even stronger criteria of invariance than invariance of order.

2. A stick represents a bundle of properties that are all implicit in the definition of "stick."

3. These properties are implicit in the kinds of actions and manipulations that can be visualized for a stick. These motions conform to the properties of rigidity and thus contain "rigidity" implicitly, but an iconic cognitive representation does not contain any element that corresponds to "rigidity" or "invariance of order."

Of these three factors, only the third is clearly synonomous with the earlier description of an iconic representation. The various positions of the stick in space represent the states of a system, and the movements represent the transitions. The invariance of the order of the painted rings is recognized because in none of these states is the green ring at one end. If the child is able to picture the results of the various movements, it never occurs to him that the green ring *is on the end*.

The example is interesting in other respects, however. The same principle is recognized more readily in one manifestation than another. This suggests possibilities for teaching and education. Yet the thing that makes it easy to recognize invariance of order of the painted rings on a rigid rod does not seem to be entirely captured by the notion of an iconic representation as defined earlier (or by the similar notion of an "intuitive" approach to the problem as described by Piaget).

Models in Scientific Theory

Perhaps the analysis of the essential problems will be furthered by drawing another analogy. The use of models in scientific theory seems related to their pictorial properties, but also to the fact that other properties than those that are needed to explain the data are implicit in the behavior of the model.

The "surplus meaning" of the constructs in a scientific model represents the properties that are block booked with those that are necessary for the fit of the model to the empirical data. This surplus meaning is unnecessary baggage as far as the explanatory value of the model is concerned, but this same surplus meaning contains the additional implications of the model that suggests new empirical studies. If these additional implications of the model are confirmed in further research, then the theory has progressed. On the other hand these additional implicit properties may hamper theory building if they are never tested but merely accepted without proof. For example, the notion of a cognitive map carries with it the tacit properties of paths on a map. One of these is that the path from A to B is available from the point of A, no matter what path was taken to A. Each segment of the map is independent of other segments that are neighboring. This property of independence frequently does not hold in human action, even in the means-end behavior for which cognitive maps were invented.

It seems likely that some of the same problems may arise in the use of concrete models to teach abstract concepts to children. The concrete model can easily contain other implicit assumptions, constraints, or degrees of freedom than those in the system it is intended to represent.

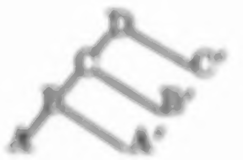
It is not easy to define the limits of an iconic representation. I have taken the essential feature of it to be that constraints and invariances to which the system is subject are not stated explicitly but *are implicitly contained in the limitations upon the variety of states* that the system may achieve, and that this variety of states is intuitively known to the individual. The intuitive knowledge seems dependent upon the fact that the workings of the system have been directly perceived so that what the individual has cognitively available is a repertoire of the states of the system and the transitions from one state to another. But it seems clear that other factors are relevant and that further analysis is required.

Differentiation of *Acts* from *Transitions*

The description of the young child's imagery suggested that the image represents both the transition in the external system, the action that produces it, and possibly the terminal state as well.

One problem in cognitive development is the separation of *the self* from the external world. One of the implications of this separation is that the child must learn that his actions form one system while the external system on which he operates is distinct. Thus the same action can accomplish different transitions in different circumstances, and different actions can produce the same end state depending upon the initial state.

Perhaps the problem can be best introduced by some examples from Piaget's discussions of grouping. One of his examples of a "grouping" is the nested sets of classes represented by biological classification, where dogs are a species and also one of the members of a genus. The genus is in turn one of the members of a class that is one of the members of a phylum, etc. For the child to understand this classification system he must in some way conceive of the entire set of nested classes; he must know what operation is necessary to go from one class to another and how to get back to the same class he started with. Piaget attempts to show the similarity between this kind of a grouping and a mathematical group as well as to point out the differences. In order to do this he uses the following notation. A represents the species and A′ all the other species in the genus. B represents the genus and B′ all the other genuses in the family. C represents the family and C′ all the other families in the class. $A + A' = B$; $B + B' = C$; $C + C' = D$; $B - A' = A$, etc. There is a rule for combining certain classes into other classes that are in the system. There is a reversibility in that any legitimate combination of classes can be separated to get back to the original class. What is lacking for this system of classes to form a group is primarily that many of the combinations of classes, $A + C'$, for example, are undefined and have no meaning. In order for a set of elements to form a group, there must be a rule of combination such that the combination of any two of them is another element of the group. The elements of a group are usually thought of as operations, and the combining of two operations means performing one after the other. Thus the set of rotations of 0, 90, 180, and 270 degrees form a group in that any one of these rotations can be followed by any other and the result is equivalent to some other single rotation in the group. Notice that there is a tacit assumption of some rotating object that these operations act upon. Thus the 90 + 270 degree operations are equivalent to 0 degrees because the object's position is indistinguishable after the two.



What Piaget seems to be trying to capture in his notion of a grouping is described in more general terms by the concept of a map, or a "graph" as it is defined in graph theory. If the operation of a system can be described in terms of states and transitions between states, then it can be represented by a graph in which the points represent states and the lines transitions between states. The set of nested classes involved in biological classification is already translated into a graphical representation above. In fact it is a particular variety of graph, a tree. Any completely connected graph fulfills the properties of a grouping—at least the additive groupings—described by Piaget. In addition it includes a variety of other patterns not described by Piaget. The defining feature of any connected graph is that there is a path from every point to every other point—and therefore a path back although it may not be a retracking of the original path. If in addition the graph is "completely connected," then there is a line from every point to every other point. Now the graph contains the full range of possible detours and short cuts that Piaget shows is implied in the notion of associativity. A graph does not have the properties of a group because there is no rule combining any line with every other line—only lines where the end point of one is the beginning point of the other can be combined into a path. The essential reason for this is that there is no meaning to a line except that it connects two specific points, so there is no basis for saying that each member of a class of lines represents the same operation. Piaget refers to this property when he says there is no rule for iteration in a grouping.

There are many kinds of systems whose functioning can be described as a graph. There is one important limitation, however, in that the graph implies that the lines are independent. This means that any line away from a point is equally available, no matter what line to that point was used. Where the lines away from a point depend upon the lines to a point—as for example where the act of hurting another person is quite different depending upon whether one has been hurt by him or not—some modification of the graph representation seems required.

But let us leave that problem to one side for the moment and ask about the relation of the graph of the states and transitions of the system to the actions of the person that bring about those transitions. These are not represented in the graphical representation. We might assume that in the child's first use of cognitive representations he intuitively performs the necessary act to bring about the transition he desires—e.g., he walks from where he is to where he wants to go. It may be true that he performs the same act in different circumstances to accomplish different transitions, but presumably there is no cognitive representation of this fact.

At some point, however, the individual needs to know how his repertoire of actions fits the pattern of transitions in the system. For example, he needs to know that "adding" is the action for finding out how many apples there are all together if Jim has three and Tom has five, and that adding is also the way to find out one's bank balance after depositing several checks. As soon as the individual must plan his actions ahead of time rather than merely acting as the circumstances dictate, then presumably he must have some cognitive representation of his own actions as well as of the external situation where his actions must be effective.

For this sort of planning it seems clear that there must be two related cognitive representations, one of the external system and one of the relevant actions. The set of actions also has various interesting properties; for example, various acts can be combined. The individual can simultaneously clench his fist and extend his arm. The fact that these two elementary acts can be combined or not at will increases the adaptiveness of the individual's behavior. Other actions can be arranged in any sequence; the individual can walk two steps forward and then one to the left; or he can walk one to the left and then two forward. And, of course, there are various incompatible actions; he cannot clench his fist and open it simultaneously; nor can he lift his left leg and then walk two steps forward. There are other act sequences which seem to represent "canned routines" like the motor actions involved in pronouncing phonemes or the muscle movements that are integrated into simple voluntary acts. Here the elementary elements are not independently combinable.

One question that can be asked of a set of acts in relation to an external system is whether or not the set of actions forms a mathematical group in relation to that system. Thus the set of acts represented by 1 step forward, 2 steps forward, and 1 step backward, 2 steps backward, etc., forms a group in locomoting along an infinite line in free space. Similarly the various acts involved in rotating an object in free space form a group. Two things are implied by such a statement. First, that the external system permits the various actions in the set to be applied in any combination and any order. Secondly, the actions of the individual are sufficiently independent of each other and of the external circumstances that all the sequences and combinations that are required to meet the criteria of a group are performable by the individual. Strictly speaking it is the set of actions (or operations) of the individual that form a group, but they only do so insofar as the states and transitions of the external system permit it. If the states and transitions of the external system do not form a completely connected graph, then the actions of the individual cannot form a group; nor can they form a group unless there is an action in the individual's repertoire that achieves every transition and there is a transition for every possible combination of acts within the set.

One must ask, of course, whether or not there is any significance to the fact that a set of acts forms a group when applied to some particular system. It seems that meeting the criteria of a group is sufficient for the individual to be able to exploit the full potentialities of the system and to achieve any desired state of the system despite external perturbations, provided they are encompassed by the system. Thus if the individual in trying to achieve state A were thrown off course, so to speak, by some external perturbation and moved involuntarily from state X to state Y, we could be assured that he could recover from this disturbance and find a new path to his goal if the set of acts within this system formed a group. Thus the existence of a "group" of actions seems sufficient for adaptive behavior toward the system, but whether it is necessary for adaptive behavior is questionable. In fact it seems quite clear that much adaptive behavior is possible without any such stringent criteria being met.

At the same time there must be some fit between the individual's actions and the external system if the individual is to plan effective adaptive behavior that can be maintained in the face of disturbances. Just what the criteria for such an adaptation are is a matter for further explanation.

Formal Representations

Iconic cognitive representations have been hypothesized to include only images or pictures of the states and transitions of the system being represented, a sort of working model of the external system. In addition to, or in place of, an iconic representation, there may be a variety of additional elements in the cognitive representation. Any such additions will be said to make the representation a formal one, although it seems apparent that there are so many kinds of formal elements that probably some classification of formal cognitive representations would be very worthwhile.

All that will be attempted in this section is to list and describe very briefly some of the variety of formal symbolic elements that may be part of a cognitive representation.

1. Verbal description as a replacement for imaged elements. The iconic representation has been described at some length. There are two aspects of it, the representation of states and transitions of a system without explication of any of the rules and the intuitive imagining of these elements. One can, of course, substitute a verbal or some other symbolic description of each state and transition for the image of it. Such a cognitive representation would constitute a set of empirical sentences in a theory without any of the underlying assumptions and definitions and intervening variables.

2. The addition of the rules of the system as elements in the cognitive representation. As these rules are gradually included in the cognitive representation, the cognitive structure comes to resemble a formal theory of the external system. Presumably an iconic representation that implies an intuitive understanding of a system and a complete translation of it into formal terms with the addition of the formal rules of the system constitutes a "complete understanding" of the system that is the goal of education—at least with respect to many bodies of knowledge.

There are, of course, many cognitive structures that are somewhere between an intuitive representation and a complete formal theory. In science these have been called proto-theories. They represent an iconic representation plus some explicit verbalized principles and rules, whose relation to the data is quite unclear. A representation, for example, of a psychological theorist's cognitive representation of human nature contains many elements whose relationships to the rest of the system are vague and ill defined from the point of view of explicit clarity, but which nevertheless must be described by a good cognitive theory. The task of cognitive theory is to state clearly the unclearness of many of our beliefs and understandings.

3. Another sort of semiformal cognitive representation is the representation of a system by an analogous model—presumably one that is more clearly, more completely or more explicitly cognized than the original. Within this general category could be included everything from metaphors and poetic symbolism, to the orbital model of the atom, but certainly such a broad category must include some radically different kinds of cognitive processes and representations. When described explicitly, models can be precisely described. There must be a one-to-one mapping of one set of elements and relationships onto another cognitive representation. In order for the model to provide any illumination of its analog, it must contain other elements and relationships that are translated back into the original as hypotheses or new discoveries. Another value of an analogous model may be that it is iconically as well as explicitly represented. If the original system is not iconically represented, then the translation into the analog may give the individual an "understanding" of the original system that he did not have before. Whether or not this understanding is more than an illusion is an open question. For example, the representation of the states and transitions of a system into a graphical representation consisting of points and lines illustrates such an analogous model. Part of what is gained is the knowledge of the theorems of graph theory, but also there is a real intuitive understanding of a spatial

map of points and lines, and this intuitive feel may be translated back so that the individual believes he "understands" better how the original system operates by thinking of its actions as locomotions from one point to another in space.

4. Thus far the descriptions of cognitive representations have stayed fairly close to the problem of describing the functioning of a system. This is important for adaptive behavior and for prediction, but it is not the only way that cognition can be organized. Concept formation, for example, the categorization of objects according to size, represents a cognitive structure applied to some external data, but it is not properly described as representing the functioning of an external system. Such concepts might be formal elements in a cognitive representation of a system, but they describe one of the ways that people cognitively organize their worlds. It would seem promising to attempt to utilize many of the basic notions already discussed to organize this kind of cognitive representation. One of the essential differences is that the lines in the graphical representation correspond to similar relationships rather than physical and temporal neighboringness. The distinction is similar to that which Piaget discusses in the distinction between part-whole relationships and sub-class class relationships.

The Identification of Cognitive Structures

One of the most important questions concerning cognitive theory is how to investigate it empirically and to ascertain what sort of cognitive structures exist. This problem is a puzzling one because it seems hard to deny that a variety of different cognitive structures may underlie the same set of adaptive behavioral acts. It is quite conceivable that a noncognitive mechanism consisting of a set of elementary independent habits could be shaped by reinforcement so that they result in adequate adaptive behavior. Similarly it is more than likely that some people add numbers through rote memory of addition facts, while others utilize a cognitive picture of a continuum and steps along it to arrive at the same answers. The task is, therefore, to detect the difference between two analogous or adaptively equivalent behavioral mechanisms.

The strategy that seems suitable for the resolution of this problem is to concentrate on the disturbances that can occur in such mechanisms. By fragmentation, interference, and the analysis of error, differences between adaptively equivalent mechanisms may be revealed. Another strategy is to study the manner in which the organism deals with new situations where the optimal adaptive behavior has not been achieved.

The cognitive structure is assumed to be composed of interrelated elements. If this is true, then how can the elements be identified? One technique is to adopt some procedure for fragmenting the structure and then to assume that the points of fragmentation must be between elements—and presumably between the relatively more separable elements. For example, Baldwin and Baum asked young children of various ages to stop talking at a signal and then to resume talking just where they left off at a second signal. The utterance was a sentence that the child was repeating—like those used in intelligence tests. Some of the youngest children could not stop talking until the sentence was completed. Others stopped at the end of the word they were saying when the signal came. Others could stop in the middle of a word, but then resumed with the beginning of the next word. Only the oldest of the sample could stop in the middle of a word and resume at the point of interruption. There were no examples of fragmentation of a phoneme—although I am not sure we could have identified it if it had occurred. This suggests that phonemes, syllables, words, and sentences are perhaps units of different order in utterances that are fragmented with increasing difficulty.

Another type of fragmentation of speech might be to ask people to say words and sentences backward. The assumption might be made that they will reverse the order to sequence of the units, but not reverse the units themselves. Thus the usual person, asked to say "trust" backward will say "start," keeping the "st" in the forward order. Whether this technique is useful in breaking up an action sequence into units is unknown. Other devices for fragmentation might be to study forgetting of a cognitive structure, to ask the person to describe it, and to record the organization of his description.

The empirical verification of the elements in a cognitive structure depends then primarily on devising some ingenious method of fragmenting the structure on the basic assumption that units are more resistant to fragmentation than the connections between units. As a matter of scientific method, it would be important, of course, to compare different methods of fragmentation and to show that they were not incompatible. Different methods need not be equivalent in the sense that they must produce exactly the same kind of fragments, but no matter what method of fragmentation is adopted, those structures that are relatively resistant to fragmentation by one method would be resistant to fragmentation by another method.

The determination of the elements in the cognitive structure is, of course, only one step in describing the structure itself. It is also important to describe the relationships between the elements. Here the kind of relationship must be taken into account. If one can imagine, for example, that a cognitive map represents a cognitive structure in which neighboringness is defined in terms of the possibility of moving from one act to another without any intervening act, this constitutes one sort of cognitive structure composed of elements and relationships among them. The same set of actions might also be cognitively represented in terms of similarities among them and represent a qualitative categorization of this set of acts. A third cognitive structure might represent this same set of acts in terms of order of difficulty of performance or an arrangement into a kind of Guttman scale. Since all of these varieties of representation of the same set of acts are possible and since the relationship between one act and another are quite different in the different cognitive representations, it seems essential to conceive of the relationships between elements as a relationship that can be qualitatively different from one structure to another.

Various empirical procedures can be suggested for identifying the relationships between the elements of a cognitive structure:

1. Generalization of learning.
2. Verbal estimates of similarity.
3. Confusion matrix of elements in recall.
4. Content analysis of verbal descriptions.
5. Content analysis of problem solving with respect to a functioning system.

These are possible strategies, but developing them into diagnostic methods would require careful empirical research.

Other topics for discussion:

1. Relation of cognitive structures to informational structures.
2. The structures underlying "primary process thought."

These will be reported later.

FROM CODABILITY TO CODING ABILITY

Roger Brown

"The old dog barked backwards, without getting up;
I can remember when he was a pup."

This couplet by Robert Frost is a fishhook flung with extraordinary precision. It pulls up a submerged experience that almost everyone has had and almost no one has talked about. And it catches (or possibly puts together) just the right experience. The dog is large and long haired and he lies before a fireplace upon a braided rug. A Pekinese on a satin cushion cannot have been intended. The couplet says "Woof!" not "Yips!"

What was the problem that Frost solved with his lines? Let me imagine it as a game. On one side of the table is Frost and on the other side are his readers. Spread out upon the table are 100 or so pictures of old-dogs-barking-backwards-without-getting-up. The pictures differ from one another in their inessential attributes. Frost has in mind just one of these 100 pictures and without pointing he is to transmit that one to his readers. He must encode it so that it can be retrieved from the array by an interested community. He gets more points for using fewer words; the game values terseness. Then, just because Robert Frost is good enough to take a handicap we require him to rhyme the last words of lines. Frost gets a good score on coding ability.

Measurement of Codability and Coding Ability

In 1953, Brown and Lenneberg used an array of colors instead of old dogs. Twenty-four different colors were shown, one at a time, to speakers of English, also one at a time. The subjects, having first glanced over the whole array, were to name each color as it appeared in such a way as would communicate to another person the color intended. There were 24 subjects and so each color was named 24 times. From these data Brown and Lenneberg worked out for the colors what they called "codability" scores. There were five different indices of codability, but the best of these was (roughly) the number of subjects giving the same name to the color.

There was a second part to the Brown and Lenneberg experiment: a recognition task carried out by subjects who had not participated in the naming. There were several variations of procedure. In one the subject looked briefly at four colors, selected from the set of 24 for which codability scores had been determined. The subject tried to hold the colors in mind for a 3-minute interval, at the end of which he was asked to pick out the critical 4 in an array of 120 that included all of the original 24. The frequency with which a color was recognized in these circumstances proved to be related to the codability of that color ($r = .523$).

Brown and Lenneberg themselves often tried to recognize various ones of the colors and it seemed to them that the "holding in mind" process was a process of linguistic encoding. Confronted with four colors, a subject probably names them and, when the colors are gone, he keeps hold of the names. Words seem to be responsive to will in a way that images are not. When the full color array appears, the subject scans it until he finds the hues to which the names best apply. A color that elicits the same name from many speakers of English, a color that can be unequivocally encoded can be unequivocally decoded and therefore easily recognized. A color that elicits many different names is not very firmly attached to any one of them, and so the name that is held in mind does not reliably retrieve the color.

"Codability" means susceptibility of being precisely encoded—in a given language. A codability score will belong to a referent in an array of referents for a linguistic community. "Coding ability" means comparative personal skill at encoding and decoding. A coding ability score belongs to a person vis-à-vis a community and with references to some domain. Coding ability does not appear clearly in the Brown and Lenneberg data and, rather than try to find it among their indices, we will turn to a subsequent experiment in which both codability and coding ability are apparent.

Dorothy Lantz completed a thesis at Harvard this year, under Eric Lenneberg's direction, which was concerned with the naming and recognition of colors, including the 24 used by Brown and Lenneberg. The measure of codability was changed. As before, individual subjects named individual hues so that others might be able to identify the hues in a larger array. However, the codability score was not the number of subjects agreeing on a name; it was in effect the actual ability of the names given to a hue to retrieve that hue. When the colors had been named by one collection of subjects, other subjects were given the names that had been supplied and were asked to identify the colors named. The codability score of a color was indexed by the average ability of the names supplied for that color by one set of subjects to suggest that color to another set of subjects.

In effect, if the various names given a color communicated well, then that color received a high codability score.

Codability measured in this new way predicted recognition with greater precision than did the codability of Brown and Lenneberg ($r = .78$). The relation between this new measure and recognition is very easy to understand. A color that is highly codable is a color that speakers of English find it easy to name or describe in a form that other speakers can accurately decode. When one subject is asked to remember such a color he has the job of naming it or describing it at Time 1 in a form that he himself can accurately decode at Time 2. The difference between the codability procedure and the recognition procedure is that the former requires people to write memos to one another, whereas the latter asks them to write memos to themselves.

Dorothy Lantz's codability is more than a matter of the language's lexicon. For each single color there was not usually a single word that would select the color from the array. A color might be called "yellow-green" or "spring-foliage-green" or "watered-down-green." This codability is still a function of the English language since it is computed for a color across many speakers. However, it is a function of the combinational potentialities of the language rather than of its lexicon. And it is not obvious how the combinations can be derived from the lexicon.

Coding ability appears in Dorothy Lantz's data as the differential personal skill at coining good names. Some subjects were regularly able to create names or descriptions that other subjects could accurately decode; others were less expert. A coding-ability score (Dorothy Lantz did not actually develop one) would reflect a subject's performance across colors rather than a color's eliciting power across subjects.

In this season of the year, when so many examinations have recently been written and read, both teachers and students will agree that the level of coding ability in schools leaves much to be desired. If you authored an essay exam and afterwards went over the "essays" with the students who wrote them, you know how incredible it is that they should have imagined you would understand they meant *that* by those non-sentences. If you wrote a multiple-choice exam, the students cannot understand how they "were supposed to know what you wanted" from what you asked. Clearly it would be a good thing if we could all improve our coding ability. We may not always want to be clearly understood but we do want to be able to choose.

Learning to Code in Early Childhood

Our longitudinal study of the child's acquisition of a first language has this year suggested to us what the tutorial mechanism may be for routine combinational or syntactic coding. It has long seemed obvious how children learn to encode and decode on the lexical level. Presumably parents go about the house naming things and actions and attributes, and children copy the performance. Presumably parents also point at things and objects and attributes and ask the child to name what is pointed at. Encoding and decoding on the level of the sentence could work the same way. Sentences, in the beginning at least, are themselves names. What they name is complicated but real enough and even picturable: things and actions and attributes, all at once and in relationship. Parents provide such names and also ask children to provide them. But the children do not pass abruptly from giving no names to giving full correct names. There is an intermediate kind of process that we call the reduction-expansion cycle which takes children from what they know to a little more than they know rather than from total ignorance to full knowledge.

The younger of our two present subjects, a girl I will call Eve, had just started to combine two, and occasionally three, words when we made our first transcription of her speech. In the months preceding, she had learned to speak many single words, chiefly nouns, but also quite a few verbs, and would go about the house all day long naming things and activities. Her most common sort of two-word utterance was, for some weeks, a combination of two nouns: such utterances as "Mommy soup"; "Eve bibby"; "Mommy eggnog." There was a regularity in these combinations: the first word named a person and the second word, a thing. This is an example of a syntactic regularity of a very simple kind, one that is not a rule of adult English.

Table 1.—The expansion-reduction cycle

Eve's utterances	*Mother's expansions*	*Eve's imitations*
Eve bibby	Eve's bibby	Eve bibby
Mommy soup	Mommy is going to have soup	Mommy soup
Mommy eggnog	Mommy has had her eggnog	Mommy eggnog

Eve's mother quite often follows the child's utterances with an adult gloss or, as we say, an expansion. The expansion is the sentence that Eve's mother judges Eve to have meant. The literature on child speech shows that making expansions is a common practice of parents (see especially H. Kahane, R. Kahane, and S. Saporta, *Development of Verbal Categories in Children's Language*. Bloomington, Indiana: Indiana University Research Center. Anthropological Folklore Linguistics, 1958) and that expansions are often made when only the child is present to hear them. The middle column of table 1 provides examples of Eve's mother's expansions. On one occasion we went back the next day and asked Eve's mother to speak her own sentences, the expansions of the middle column, and to ask Eve to imitate them. Mother said: "Eve, you say what I say." And she went on: "Mommy is going to have soup." Eve came back with: "Mommy soup." This, of course, is the original utterance with which we began. Of course the cycle is not always so perfect and to get the few ideally illustrative instances of table 1 we had to pick from the data for two children. However, putting together results this year from data we have collected in previous years (R. Brown and C. Fraser. "The Acquisition of Syntax" in C. U. Cofer and Barbara Musgrave (eds.) *Verbal Behavior in Learning*. New York: McGraw-Hill, 1963), there is much evidence of an interaction cycle between mother and child that amounts to a pair of reciprocal transformations: the child reduces its mother's speech and the mother expands the child's.

The transformation accomplished by the child is more determinate than the transformation accomplished by the adult. One could instruct a machine to do what Eve has done. The instruction would be: "Retain the nouns in the order given and delete the rest." One could not tell a machine how to accomplish the mother's expanding transformation. Clearly she retains the nouns in the order given and adds grammatical function words: inflections, auxiliary verbs, articles, and prepositions. But which ones and in what order? The three expansions of two nouns presented in table 1 are all different—the examples were picked with this in mind. The expansion process is not fully automatic.

We have done some work with children's imitations of adult speech (R. Brown, C. Fraser, and Ursula Bellugi. "Explorations in Grammar Evaluation." In U. Bellugi and R. Brown (eds.) *The Acquisition of Language*. Monographs of Social Research in Child Development, 1964, Whole No. 92, p. 79-92.), and Eve's performance is typical of children who are forming their first sentences. Whatever the length of the adult model sentence, it will be reduced by children of Eve's level of development to just two or three words. The utterances the child produces for which he has no immediate model, his autonomously generated word combinations, observe the same restriction on length. We believe that he operates under a severely limited sentence programing span. It is this span that compels the child to reduce adult speech but the reductions are selective on certain consistent principles (Brown and Fraser, 1963), and span alone does not dictate these principles. Eve, in our three examples, retains nouns in the order of the original and drops function words. More generally, children at this stage retain reference-making words, nouns chiefly, but also some main verbs and adjectives. They drop the little words that differentiate grammatical constructions. The autonomous utterances of children at this stage are just like their imitations. It is a "telegraphic" English they speak.

Eve's mother believes that her expansions, the sentences of the middle column, are the meanings Eve had in mind when she produced the noun-plus-noun combinations of the left column. Eve's reductions back to the original which appear in the right column might suggest that mother is right. Suppose that the two participants in this interaction were adults, bilingual in French and in English. Suppose that Eve's original utterances were in French and that her mother's sentences were translations into English. Suppose that Eve's final sentences were translations of mother's English back into French. Since we end with the sentence we had at the start, one would say that the mother's translation of the child's speech had been proved correct by the method of back-translation.

However, there is one great difference between the back-translation case and the present interaction. Back-translation works with utterances produced out of context; expansion does not. Some time after the original interaction we gave Eve's mother some of Eve's former noun-plus-noun combinations and asked her to tell us what they might have meant. As table 2 indicates Eve's mother could think of a number of possible expansions. Her expansion transformation cannot be fully determinate with words as the only input. In the actual situation, however, a single expansion always seemed more appropriate than any other. When Eve said "Eve bibby," mother was putting the bib round the child's neck. When Eve said "Mommy soup," it was nearly lunchtime and mother often had soup for lunch. When Eve said "Mommy eggnog," there was no eggnog present or impending but there was eggnog in the mother's recent past. The expansions produced in the situation are always to the nearest semantically appropriate sentence.

Table 2.—Expansions made without situational support

Eve's utterance	*Mother's expansions*
Mommy soup	Mommy's soup
	Mommy is going to have her soup
	Mommy has had her soup

We are not certain that Eve always or even usually means what her mother thinks she means. It is possible that she is simply naming two ideas that the present situation has brought to her mind. Why should she always name them in the order: first the person and then the thing? In the sentences Eve's mother speaks if there are two nouns, one naming a person and one a thing, they usually occur in this order: person and then thing. The two nouns have articles and prepositions and inflections all round them but if one attended only to the nouns in these sentences one might easily extract the rule: persons first and things second. We think it possible that the rough regularities of order discoverable in a child's telegraphic English are a syntax of the nouns and verbs and adjectives in adult sentences with everything else disregarded.

Eve's mother is probably wrong in her belief that Eve now has in mind the meanings expressed by expanded versions of noun-plus- noun combinations. One reason for thinking mother is wrong is that Eve sometimes produces combinations that even mother cannot interpret. Another reason for thinking so is that Eve's words and actions following the interpretation sometimes seem to disconfirm it. But if mother is wrong now, she will not always be so. Eventually Eve will think in terms of personal possessions—the terms appropriate to "Eve's bibby." Eventually she will order events in time and in terms of their completeness and regularity as one must to speak of having had eggnog and being about to have one's accustomed soup. By expanding the child's words into the nearest sentence appropriate to the circumstances, a mother may teach a child to conceive of those circumstances as they are conceived in the community and to code them as adults code them. Perhaps a mother who is convinced that a child always means something and that a mother can figure out what it is provides good conditions for a child to learn to mean something and to say it.

By the age of 3 years, many children are "printing out" all their function words and mother does not do much expanding. By this age, too, the child's discourse is not so closely bound to the present situation. As he begins to talk of things past and future and things only imagined, it must become difficult to expand his sentences because it is difficult to tell from the situation what he ought to mean. Parental responses cease to be expansions of what the child said and come to be utterances *predicated upon a certain interpretation of what the child said.* The response to "mommy going have soup" becomes "Yes, I'm hungry," or "Oh, is it nearly noon?"

The follow-up sentence predicated upon an interpretation of a preceding sentence is characteristic of adult conversations insofar as these conversations have continuity. In these circumstances how can a speaker judge if he has been understood? When a sentence has action implications for an auditor ("Please pass the soup.") comprehension is easily separated from incomprehension. But when the only follow-up is a sentence responsive to the original, incomprehension can be difficult to detect. Roughly the speaker must judge whether or not the sentence that follows his own belongs to the population of sentences that might be inspired by a correct understanding.

If Eve's "Mommy going have soup" elicits an abstracted "Yes, that's right; sit up and eat your lunch!" who can tell whether Eve has been correctly "received"?

In social intercourse, including teaching, there are very many reasons for not signaling incomprehension, and we have a set of formula sentences and mechanical rejoinders that serve to keep things moving. We have often said "Right!" when we should have said "What?" A teacher lecturing to a class cannot evaluate comprehension or even attention. He only asks that the class members stop short of putting their fingers in their ears.

It is not difficult to think of a communications reform that would greatly improve academic instruction. Let students and teachers as receivers learn to say: "I do not understand you; kindly say it another way." Let students and teachers as speakers learn to react to such requests with pleasure and recode zestfully. I have the impression that if these reactions were established, education would be much improved in the local high school and at Harvard. But this is a science fiction reform that almost certainly cannot be accomplished. False signals of comprehension are necessary to preserve the self-esteem of both teacher and student. Perhaps the difficulty is even deeper. It may be that decoders do not always have internal tests which tell them when comprehension is lacking. Perhaps for some subject matters the decoder does not know the feeling of understanding and so, even with perfect personal security, could not say when understanding is absent.

A Coding Game

It is possible to devise games that would test coding ability and that might teach general lessons about how to encode and decode. Such games would be at least as much fun as spelling bees and the intellectual value should be greater. The model is Charades, a game of enactive encoding and decoding. But Charades is possible, as a game in which large differences of personal skill can appear, only because there are not conventional enactive symbols for most ideas.

A linguistic coding game must find ideas or referents which are not easily named by everyone. The most effective way of making the coding of a particular referent difficult is to place it in an array where it is not obviously distinctive. One dog-barking-backwards-without-getting-up in an array of cats can simply be encoded *dog;* in the array we imagined for Robert Frost, the problem was more difficult. A solitary scratch on a table top is highly codable but some table tops have thousands of scratches. Think of just one of these and figure out how you could, without pointing, communicate that one to another person looking at the full array. Notice that much more than language is involved; one must make an informational analysis of the total field. Encoding can also be made difficult by ruling out-of-bounds certain kinds of language. In the case of the scratch on the table top, for instance, one might prohibit geometrico-technical descriptions of the type: "It is in the northeast quadrant on a 45° line from the center." Certain kinds of coding can also be excluded by restricting exposure to the referent. In the difficult-to-code line drawings that William Kessen has been using in his appetite-for-information research, the subject does not see the figure long enough to count the number of sides.

A coding game need not be limited to the identification of referents. One might ask subjects to encode a performance as Piaget did in the work reported in *The Language and Thought of the Child.* One child watches as a syringe is operated and then has the task of explaining to another child how to do it. The test of understanding can be the adequacy of the other child's performance. John Flavell, in his current work on egocentrism of speech, has had one child learn how to play a new game by watching others and has then required that child to explain it.

If a group had a fund of shared experience the game could be to bring to mind, vividly but with few words, something everyone can recall. A busload of underprivileged children returning from a day of "cultural enrichment" in New York's museums or concert halls could play this game. How to bring to mind a painting everyone had noticed when the name of that painting is not known? To make things difficult one could encode shared moments that no one has discussed: he point in his talk about Hogarth when the museum lecturer started to say *slum* and then caught himself.

The coding game, as we have thus far imagined it, involves vocabulary and grammar and the ability to make an informational analysis of a set of referents or a performance, but something important has been left out. An effective encoder must have a good grasp of the informational requirements of his auditor. When the encoder simply projects his own information to the auditor without regard for the auditor's real circumstances, speech is "egocentric" in Piaget's sense. One of the circumstances in which adult speech is often grossly egocentric is in the giving of directions. "How can I get to Harvard Square?" asks a visitor from Minnesota. "Take the Drive to the Anderson Bridge, turn right and keep going until you come to the kiosk."

The baseline case is encoding at Time 1 for oneself at Time 2. The ability to imagine your own informational requirements at a later time is an important one. Reading old lecture notes, you discover that they were written to become unintelligible the day after the exam. Edith Kaplan did some work a few years ago at Clark contrasting descriptions of novel drawings written for oneself at some future time with descriptions written for others. Memos to oneself are, of course, about half as long as memos for others. Memos to oneself can encode in idiosyncratic ways that will not work for others: "A figure that looks like the abstraction on my living room wall."

John Flavell has taken up Piaget's egocentrism-socialization problem and done some further imaginative things with it. For example, a child is asked to teach a game to a blindfolded adult on one occasion and to a seeing adult on another. Some of the younger subjects had very little appreciation of the requirements of the blindfolded adult; they said such things as "You must pick up this" (pointing) "and put it there" (pointing).

In another experiment, Flavell had the encoding child speak simultaneously to three other children (the encoder was the police chief and the decoders were policemen in squad cars). The chief has information units *a*, *b*, *c*, *d*, and *e*. One listener (L_1) already knows *a*; another (L_2) knows *a* and *b*; a third (L_3) knows *a*, *b*, and *c*. Think of the interesting problems that can beset the chief. For instance, he can be asked to send a message that will put all three listeners in possession of the full information and not to send anything unnecessary. Since all know *a* and *a* is all that L_1 knows, he must send *b*, *c*, *d*, and *e*. This might be called "teaching to the bottom of the class." The problem changes if we suppose that L_1, L_2, and L_3 are free to tell one another what they know. Then the chief need only communicate what none knows. This is teaching to the top of the class.

Flavell's associate, Charles Fry, has made an effort to teach communication skills to 5th-grade children. They played a game of encoding and decoding with unfamiliar geometric designs. The training produced some positive transfer to closely similar coding problems but not to more remote problems. However, it is easy to see why the transfer was limited and to imagine how it might be extended. It is encouraging to read that the children were greatly taken with the game and had very animated discussions about the shortcomings of this or that message and the requirements of a good message.

Since we began by quoting Robert Frost, we have earned the right to close with a few words about "creativity." Good encoding is, of course, a creative act and so is good decoding (though the latter is easy to feign and hard to test). Creative encoding involves the production of novelties, of course, but the novelties must be apt. They must be apt extensions of grammar and lexicon and metaphor and connotation and sound symbolism. And there must be recognition of aptness by a community that has all the elements and all the rules but had not used them to produce this particular effect. *Creative* is a word to apply to the way a person operates with a cognitive system within a community that shares the system, not a word to apply to all innovators and not a word to apply to all practitioners of the fine arts.

THEOREMS FOR A THEORY OF INSTRUCTION

Jerome S. Bruner

In what follows, I will set forth some propositions about instruction. There is bound to be foolishness in such a preliminary exercise. Both in the interest of clarity and to render the foolishness more discernible, I use the propositional form so that each theorem can stand on its own bottom. There is a minimum of qualification, for any proposition can be made to seem reasonable if enough qualifications are attached. Better to be flat-footed and wrong than guardedly indeterminate.

1. Nature of a Theory of Instruction

1.1. A theory of instruction is *prescriptive* in the sense that it sets forth rules concerning the optimal way of achieving knowledge or skill. By the same token, such a theory provides a yardstick for criticizing or evaluating any particular way of teaching or learning.

1.2. A theory of instruction is, in the strict sense, a *normative* theory. That is to say, it sets for itself the task of establishing a criterion (the production of certain kinds of learning or certain kinds of learners), and then states the conditions for achieving such an end result. But a normative theory, to be useful, must have a high degree of generality and cannot be related to the achievement of particular end results. These should be derivable from the general theory.

1.3. Descriptive theories of learning or development, though they may imply with more or less ambiguity a prescription for optimal learning, *do not do so directly*. Though the difference between continuity and discontinuity as descriptions of the learning process may imply different strategies for a learner, to take an example, they do not specify these implications. Does the continuity position which holds that learning is an incremental accretion of what is common to our successes imply, for example, that it makes no difference how many things are presented to the learner at once, since the reinforcement-extinction process will sort them out anyway? It could specify such a rule, but clearly such a rule is incorrect, in much the same way as the rule of "one-thing-at-a-time" is incorrect, though it follows from the strict discontinuity position that we pick up only that narrow set of things to which we are attending. Whichever view is correct, neither of them is concerned with how one devises a teaching or learning strategy that would be best. Theories of learning say what happened after the fact.

1.4. It follows, then, that there is some *independent form of research activity* that is necessary for the establishment of a theory of instruction.

1.5. It also follows, however, that where there is a contradiction between a theorem in a theory of instruction and one in a theory of learning, it cannot be decided *a priori* that the former invalidates the latter or *vice versa*. All that seems obvious is that contradiction between the two cannot be tolerated. In short, there must be some *congruence* between a theory of how to optimize a learning sequence and a theory that describes what happens when learning occurs.

1.6. It can be concluded from this that the two types of theory have a *complementary relation* with each other, rather than one of them deriving from the other or being supplementary to the other.

2. Scope of a Theory of Instruction

2.0. There are at least four aspects to a theory of instruction:

2.1. A theory of instruction should specify the *optimal experiences or encounters that predispose* a learner to learn. These are the so-called antecedent conditions for good and poor learning or for different types of learning, and they range over a wide spectrum of "determinants." They include not only the normal set of specifications about personality growth—e.g., the nature of relationships between parental figures and child—but also take into account the nature and degree of richness of the environment of the young child: linguistic, social, opportunities for overt skilled muscular activity, movement, and constraint, etc. A comprehensive statement of predisposing conditions should be related to any and all criteria of learning. It should illuminate not only the task of producing a generation of spontaneous children of a kind valued in our democratic society, but also explore what produces ideal learners in other kinds of societies. Examples given in this paper are drawn exclusively from the context of education in a democracy.

2.2. A second feature of a theory of instruction relates to the *structuring of knowledge that is optimal for comprehension.* Optimal structure refers to the set of propositions from which a larger body of knowledge can be generated, and it is characteristic that the formulation of such structure depends upon the state of advance in a particular field of knowledge. In a later section, the nature of different optimal structures will be considered in more detail. Here it suffices to say that since the goodness of a structure depends upon its *power for simplifying information*, for *generating new propositions*, and for *increasing the manipulability of a body of knowledge*, structure must always be related to the status and gifts of the knower. Viewed in this way, the optimal structure of a body of knowledge is not absolute but relative. The major requirement is that no two sets of generating structures for the same field of knowledge be in contradiction.

2.3. A third feature of the theory of instruction is a *specification of optimal sequences of presentation* of materials to be learned. Given, for example, that one wishes to teach the structure of modern physical theory, how does one proceed? Does one present concrete materials first in such a way as to elicit questions about recurrent regularities? Or, does one begin with a formalized mathematical notation that makes it simpler to represent regularities later encountered? What results are in fact produced by the use of each? The question of sequence will be treated in more detail later.

2.4. Finally, a theory of instruction should specify the *nature and pacing of rewards and punishments* in the process of learning and teaching. Intuitively, it seems quite clear that as learning progresses there is a point at which it is better to shift away from extrinsic rewards such as teacher's praise toward the intrinsic rewards inherent in solving a complex problem for oneself. So too there is a point at which immediate reward for performance should be replaced by deferred reward. The shift rates from extrinsic to intrinsic and from immediate to deferred reward are poorly understood and obviously important. Is it the case, for example, that wherever learning involves the integration of a long sequence of acts, the earliest shift should be made from immediate to deferred reward and from extrinsic to intrinsic reward?

3. Predispositions to Learning

3.1. Learning and problem-solving require the *exploration of alternatives*. Yet, in the interest of safety and economy, it is not efficient for a learner to explore all possible alternatives in solving a problem or in learning how to do something or in seeking to understand a matter. In any particular culture, moreover, there will be predisposing factors that either lead to or suppress an individual's tendency to explore and consider alternatives. These include such things as the degree of intellectual stimulation provided to the child by his mother, various taboos that exist in the wider society, etc.

Instruction has as one of its objects the optimizing of exploration among alternatives. In fulfilling this function, it is constrained by three considerations.

3.1.1. Instruction must *minimize* the risks attendant upon exploration. Learning something with the aid of an instructor should, if instruction is effective, be less dangerous than learning it on one's own. That is to say, the consequences of error should be rendered less grave in terms of physical harm, loss of face, feelings of degradation, etc.

3.1.2. Instruction must *maximize the informativeness of error*. Confusion and information overload produce a reduction in the effective range of exploration carried out by a problem-solver. Error that does not carry information leading to its correction is a principal source of such confusion. Whether by the choice of materials to be dealt with or the nature of the learning situations that are arranged or by the provision of corrective feedback at the appropriate time, instruction reduces confusion by rendering error informative.

3.1.3. Instruction seeks to *vitiate the effects of previously established constraints on exploration and curiosity*. There are instances in which the predisposing effects of family and culture either constrict or overextend explorativeness. Once such predisposing conditions are known, instruction has as its object to alter their effects to a form that is appropriate to the task being learned. In certain instances, instructional activity of this kind will run counter to the values of a society, in which case the issue becomes one that is decided on the basis of a broader criterion than the purely educational one.

3.2. Since the relation of instructor to student—whatever the formal status of the instructor may be, whether teacher or parent—involves the relation between one who possesses something and one who does not, there is always a special problem of authority involved in the instructional situation. The regulation of this authority relationship affects the nature of the learning that occurs, the degree to which a learner develops an independent skill, the degree to which he is self-confident of his ability to perform on his own, and so on. Such matters as identification with teacher or parent, the nature of the learner's attitude toward instruction, and the rest—all of these affect the quality of learning. No instructional situation can avoid the task of deciding how to regulate this matter. *The relation between one who instructs and one who is instructed is never indifferent in its effect upon learning.*

3.3. Since the instructional process is essentially social—particularly in its early stages when it involves at least a teacher and a pupil—it is clear that the child, especially if he is to cope with school, must have *minimal mastery of the social skills necessary for engaging in the instructional process.* Alienation from the society, as in the case of poor migrants who come into the great American cities, or inability to deal with social requirements, as in bush children, block the child from benefiting from school.

3.4. There are certain highly generalized intellectual skills upon which a child's knowledge depends. One is language; another may be simple manipulative skills; still another may be the ability to delay reaction. Later mastery of more complex skills depends upon prior acquisition of component elementary ones. *Early training in elementary intellectual skills is, then, critical for later development.* There likely are critical periods in the use of certain linguistic forms or in the development of certain forms of imagery—critical periods after which learning becomes increasingly difficult to achieve. While this is a matter relating more to sequence of instruction than to predisposing factors in learning, it is mentioned here since it relates to preschool extrascholastic activity. Toys and games reach the child long before he reaches school. Are bush children in West Africa, for example, hampered in later development by a lack of toys with mechanical and geometrical constraints? Is the child who has little linguistic interchange with his mother permanently handicapped in language and thought?

3.5. It is common observation that there are *differing attitudes toward intellectual activity* characterizing different social classes, the two sexes, different age groups, and different ethnic groupings. These culturally transmitted attitudes pattern the use of mind. Some cultural traditions are, by count, more successful than others in the production of various patterns—the Jews, for example, in the production of scientists, scholars, and artists. Anthropology and psychology investigate the ways of "tradition" or "role" affects attitudes toward the use of mind. A theory of instruction concerns itself, rather, with the issue of how best to utilize a given culture pattern in achieving particular instructional ends. One does not begin instruction in mathematics in the same way with ritual-minded Wallof children in Senegal and with explorative middle-class children in Winnetka, Illinois. *Instruction always involves a decision on this issue.*

3.6 One may characterize *persistent styles in the use of the mind* that require special attention in the presentation of material to be learned. The respective roles of manipulation, imagery, and symbolization in problem-solving is one such characterization. It is not clear to what extent, for example, "geometers" and "analysts" appear very early in life as types in the learning of mathematics—whether it is early training or inheritance that is involved. Persistent differences in the degree to which conclusions are arrived at impulsively or reflectively have also been observed in many studies of individual differences. A gain in efficiency of instruction can be achieved by examining the course of development of persistent styles or by attempting to reinforce incipient styles. Style, in any case, is an important predisposition to certain kinds of learning. *Optimization of learning results from a matching of learning materials to the style of a learner.*

4. Structure of Knowledge

4.1. Any set of statements about any subject can be reduced to a simpler set that is *more economical and generative.* Grasp of such a set of propositions should have the effect, then, of simplifying a domain of knowledge and providing the learner with a basis for generating predictions about further observations. In some cases, the reduction is drastic and dramatic, as in mathematics and physics. In others, less so: as in history or literature. Yet, since everything cannot be taught about anything, it is necessary to find just such a reductive set of propositions or principles if teaching is to be done at all. At very least, the grasp of a set of basic ideas should aid the learner in segregating what is relevant from what is trivial or redundant.

4.2. The worth of a set of simplifying and generative propositions is determined by their power to fulfill the function of simplifying and generating. But this power is constrained by the *manipulability of a set of propositions* in the hands of a given learner. It follows from this that a set of propositions that is good for one age or one background may not be good for another. For manipulability depends upon a match between the analytic tools being used and the degree of mastery and power already attained by the user. A brilliant intuitive mathematician (age 8) would wither at the task of mastering precise algorisms. *In addition then to characterizing a propositional structure by its power, it is necessary to characterize its effectiveness in the hands of a particular learner.* This is not intended as a reinstatement of the old idea of "readiness," as we shall now see.

4.3. *Any problem that can be solved by presently available means can be solved by simpler steps than those now employed.* This, in oversimplified form, is Turing's Theorem. Any structure of propositions that effects a productive simplification of a body of knowledge can, similarly, be restated in a simpler form that is both powerful and effective in the sense of being within reach of a learner. The translation may lose in power or precision, but it will still be simplifying and generative—and its gain will be in effectiveness for the user. The inventive task of the teacher or curriculum-maker is to find the translation of propositions that is appropriate to the powers of the person being asked to master it. The relevance of this theorem will become evident in the next section. Any subject, in short, can be taught to anybody at any age in some form that is honest and useful. The burden of proof is upon those who teach, as well as those who learn. It is meaningless to say that the calculus cannot be taught in the first grade. There are useful things about calculus that can be and with profit to later learning.

4.4. *What one knows about something cannot be separated from the order and manner in which the knowledge was acquired.* For "knowing something" is not simply possessing it, but rather, being able to retrieve, manipulate, and use it. Retrieval and use are determined in part by how one learned.

4.5 At a very minimum, any body of knowledge can be represented in three ways: (1) in terms of a set of actions to be performed to achieve certain results; (2) in terms of certain summary images that "stand for" the subject in the sense that Magna Carta "stands for" constitutionality in English history, or a diagrammatic triangle "stands for" the concept of triangularity and (3) in terms of a set of symbolic or logical propositions strictly governed by well-defined laws of formation, transformation, induction, implication. With respect to a balance beam, for example, children can use it without having much of an image of what it is, but their use can be highly skilled. Watch young children on a seesaw. We say that they "know it in their muscles." Or they can go beyond this to an intuitive or ikonic representation of it, and even refine this to a considerable geometrical nicety. And finally, it is possible to describe or represent balance beams and seesaws in terms of Newton's law of moments and to apply a mathematical notation to it that takes one far beyond the direct experience of manipulating a balance beam or of drawing a picture of it, no matter how diagrammatic.

4.6. The three general systems of representing or structuring knowledge can be described as parallel in the sense that doing, picturing, and symbolizing *can be pursued without interference one with the others.* To put it in a homily, a great shortstop can superbly perform his fielding of a curving grounder in a manner that is quite independent of his knowledge of the differential equations that describe the path of the ball through space.

4.7. But it is also possible to *translate in greater or lesser degree each system of representation into any other.* A great administrator, while he can operate brilliantly without stating a theory of administration that guides him, can also (by the exercise of a different set of skills) represent his actions by a system even so symbolized as March and Simon's mathematical theory of administrative behavior. The burden of evidence points to the fact that translation of a body of knowledge into the three systems of representation has the effect of altering and enriching each of the systems.

4.8. Where an individual is starting to learn a body of knowledge completely from the beginning, *the task of instruction involves some optimal orchestration of the three systems of representing that knowledge.* In general, since the course of development in children runs from enactive representation through ikonic representation to symbolic representation, it may well be that that sequence is the best starting-technique with children. In adults or older children, where language provides a bridge between the other systems of representing knowledge, there are often multiple strategies that can be used. We shall return in the final section to this consideration of sequence. It is noted briefly here to indicate that structure and sequence bear an intimate relationship to each other.

4.9. Organized bodies of knowledge, the so-called disciplines, vary in terms of *the degree to which they have been subjected to effective and economical representation.* Some are highly symbolized in terms of the mathematical rules governing them—such as physics. Others, notably history and other fields of social studies, are much more loosely summarized by general propositions. It does not necessarily follow from the advanced state of development of a field of knowledge that it should be introduced to a learner with the fullness of its symbolic apparatus. It is often the case that a manipulative and picturable knowledge of phenomena is necessary before a learner can grasp the referents of a symbolized representation. It is notably true, for example, that a grasp of intuitive geometry must precede more metrical knowledge of geometrical properties and that both of these are necessary underpinnings for the beginner in analytical geometry. The general concept of "prerequisites" in a curriculum or in a course of learning relates not only to the relation between different subject matters but in an even deeper sense to the means of representing knowledge in one field or subject at different stages in the course of learning. It is this system of "internal prerequisites" that has been referred to as a "spiral curriculum."

5. Conduct and Affect

5.1. One objective of learning, over and beyond the mastery of a body of knowledge, is to *create a better or happier or more courageous or more sensitive or more honest man.* We take as a first theorem that the conduct of life is not independent of what it is that one knows nor is it independent of how it is that one has learned what one knows. This is not to deny that there are knowledgeable and innocent sinners and knowledgeable and innocent saints.

5.2. Kowledge, in sum, is *instrumental to values.* It can be used to amplify evil intent or magnanimity. The possession of certain bodies of knowledge does not in itself predispose one to either decency or its opposite. In this sense, the structure of curriculums, as far as content is concerned, need not be defined in terms of the values they impart. Rather, they should be constructed in terms of the instrumental assistance that knowledge imparts to the exercise of values. Thus, if it is necessary for people to live within a democratic society, one would choose to teach as much as could possibly be presented well about the conditions that led Western man to redefine his role from that of subject to that of citizen. But by the same token one should, in the interest of furthering and strengthening the expression of democratic values relating to rational criticism, also present the occasion of great deviation from democratic ideals—from the fall of the Roman Republic to the emergence of modern totalitarianism.

5.3. The effectiveness of values depends not only upon knowledge of the instruments of their expression, but also upon *a sense of the alternative ways in which one can succeed or fail in their expression.* In this sense too, then, the teaching of democratic ideals must, for example, avoid the presentation of a position as the only position that can naturally exist. The same would hold for the teaching of manual training, where there are also alternative ways of proceeding in the interest of making something that is strong or beautiful or useful.

5.4. Instruction in the values of a society or in the values of a profession or group or family is based upon the *acceptance and/or rejection of axiomatic or unprovable propositions about preference.* Such statements of preference are unprovable in the special sense that even when one chooses one way of valuing over another on "empirical grounds," the basis for the choice depends upon the use of an arbitrary criterion. The choice between freedom or slavery cannot be based upon "scientific evidence" concerning the consequences of the two states. Rather it must be based upon how one values the two consequences, and that depends upon underlying convictions that are not open to proof or disproof. Knowledge has the effect of making one realistic about consequences. In this sense, ordinary learning has a bearing upon the exercise of conviction.

5.5. *But instruction in the underlying values, convictions, and attitudes of a society involves a separate realm of technique and pedagogy.* I should prefer to leave the issue at that and propose that what is needed as an adjunct to a theory of instruction is a theory of belief and its inculcation. It is worth noting in passing that when one and the same institution is charged with the forming of convictions and with the imparting of knowledge, there is often a conflict and the latter suffers.

6. The Nature of Optimal Sequence

6.1. *Sequences of learning can be devised to optimize the achievement of different objectives.* One cannot, therefore, speak of *the* optimal sequence for presenting a body of knowledge.

6.1.1. There are *optimizing strategies* that have as their objective a particular form of representation, in the sense that that expression was used in a prior section. Thus, one would not teach the practical geometry of shopwork (if good carpentering were the objective) by the same means that one would employ in teaching geometry of a more highly symbolized nature.

6.1.2. There are strategies that have as their objective to *achieve a type of learning* that is as quick as possible or as proof as possible against disruption by stress. An offshore racing sailor learns sail-changing so thoroughly and fluently that he will be able to carry out a sail change in gale conditions. Such knowledge might hinder the imaginative activities of a naval architect. A pianist practicing for a recital overlearns in a fashion that makes it possible for him to attend exclusively to the interpretation of a piece rather than its sheer performance.

6.1.3. There is one particular class of strategies that relate to the presentation of materials in such a way as to (a) *increase the likelihood that knowledge gained will be converted into economical conceptual structures*, and (b) *increase the likelihood as well that the learner will recognize the transferability of what has been learned to new situations where comparable material is likely to be encountered.* Such optimizing strategies are peculiarly relevant to learning that occurs in school, since it is clear from considerations of time alone that in the limited exposure to a subject provided in school, conceptualization and transfer must be optimized if a pupil is to get anything from his instruction at all. It is with this class of strategies, consequently, that the following propositions are principally concerned.

6.2. The following hypotheses are proposed as relevant to the kind of learning mentioned directly above:

6.2.1. If the underlying economical structure of a set of facts is to be grasped conceptually and readily transferred to new instances, then it is better to learn the basic conceptualization *by induction from particular instances.* In this manner, a learner grasps both the generalization and a range of its applicability at the same time. There is sufficient research on conceptual learning to indicate the utility of this rule, though much more work is needed to examine its details.

6.2.2. The learning of a conceptual structure seems to require that there be *contrast between a positive and a negative instance.* That is to say, to understand a reciprocal relation between nation states, it is necessary to have the contrast case of a non-reciprocal one—for example, Britain and America today and Britain and America in the 18th century. Or to grasp algebraic commutativity of the form [3 x 4] = [4 x 3], it is necessary to grasp a non-commutative case, as in natural language where [black shoe] = [shoe black]. The logical importance of contrast is evident; the psychological importance is attested to by a decade of research on conceptualizing.

6.2.3. *Premature symbolization* of a conceptual relationship may have the effect of leading a learner away from the relationship between symbols and things symbolized in much the way, for example, that quadratic functions in algebra are often learned without the learner's having a sense that such equations are a way of treating instances of regularity in nature where there is the same number of classes as there are elements in each class. It is necessary, if transferable conceptualization is to result, for the learner to have some sense of the manipulative or picturable referent to which symbols apply. This proposition is so obvious that it should not need statement, yet it is the one most often overlooked in the devising of materials to be learned.

6.2.4. The "*size of step*" that one should employ in presenting a sequence of material to be learned varies as a function of the present ability of a learner and also as a function of the kind of eventual ability that one wishes to produce. If, as is often the case, the eventual objective of learning is to produce a learner capable of large inductive leaps and daring attempts at transferring knowledge to new situations, then the course of learning should provide opportunity for practicing such intellectual activity in the protected situation of learning. There should be practice in bold guessing. Let it be noted in passing, however, that the learner should be equipped with correction strategies that permit him to recover when a leap has been wrongly directed, but to that subject we turn shortly.

6.3. *It is rare for everything to be learned about anything on one* *encounter*. This is particularly the case where what is learned about anything is its relationship to something else. Thus, on first encounter with the study of the 11th century we meet William the Conqueror. It is difficult to grasp very much of his relatedness to the broader European tradition, about the position of Normandy in France, about the condition of impoverishment of the Saxon kings, etc. We take it as obvious that just as one plays a recording of a musical composition many times to appreciate its structure, so one revisits the Norman conquest of England. Yet, it is often the case that in the interest of coverage we "move on" to new materials before we have licked the pot clean. A full sense of the structure of a domain of knowledge requires revisiting the same subjects repeatedly and with different perspective. It is this too that is involved in a "spiral curriculum."

7. Reinforcement and Information

7.1. One may distinguish between *two separable terminal states that may follow upon an attempt to know something or master some task*. One of them is *success or failure* and has to do with whether or not the learner has reached some criterion state—i.e., whether he has progressed from a present state of knowledge or skill to some desired state of knowledge or skill. Success and failure are inherent to the task at hand and not external to it. You solve it or you do not. Such terminal states result from the learner's use of operations to reduce the discrepancy between where he is and where he wants to be—operations such as addition, subtraction, reasoning, constructing, remembering, looking up something, and so on. The other class of terminal states are *reward and punishment*. Successful completion of an act may or may not be rewarding. Unsuccessful action may be either punishing or not. To the extent that reward and punishment are controlled by an outside agent—a teacher or parent or one's peers—the reward of success in and of itself is reduced. That is to say, if successful problem-solving becomes only a means to some extrinsic reward such as a prize or praise from a loved one, then the process of problem-solving becomes secondary to the achievement of an external gain. Where failure is concerned, external punishment for failure has the effect of reducing the informativeness of failure. Failure of achievement in problem-solving cannot be converted into corrective information when the consequences in punishment are above a certain threshold. In a word then, the use of reward and punishment seriously affects the informative utility of successful and unsuccessful attempts at problem-solving.

7.1.1. *Success followed by strong external reward will have* *the effect of increasing the likelihood of the same kind of performance another time.* This result may or may not be desirable. It is not advisable if the achievement is a transitional state enroute to more powerful learning. A study by Caron and Stephens (1963) indicates that successful problem-solving without external reward in a task involving the learning of a physics principle leads the child to attempt a better method on later attempts. Unpunished failure, on the other hand, leads to a tendency to repeat the act in order to discover what went wrong.

7.1.2. *Error with consequences of punishment from outside is more likely to disrupt behavior* than to provide a basis for correction. Even studies on learning in rats suggest that optimum learning occurs at a moderate level of motivation that does not place too heavy a price on failure. Again, one can cite studies of learning in the rat. Where an extrinsic punishment has been independently established as dangerous and inescapable, the use of that punishment for incorrect performance in a learning task will not only slow learning down drastically, but will also reduce the amount of trial and error behavior exhibited by the animals (T. L. McCulloch and J. S. Bruner. "The Effect of Electric Shock Upon Subsequent Learning in the Rat." *Journal of Psychology* 7:333–336; 1939).

7.1.3. In short, there is a *dual function* provided by success and failure on the one hand (a function of *informativeness*) and by reward and punishment on the other (a function of *need reduction*).

7.2. The balance between the intrinsic rewards of problem-solving and the external rewards that come as a sequel pose a threefold problem: a problem *of the nature of the balance*, a problem *of phasing the balance over time*, and a problem *of segmentation.* Each involves a compromise between inherent satisfaction and external reward. We consider the three problems in turn.

7.2.1. Totally dispassionate problem-solving is probably limited to a few saints. That is to say, in most cases children and adults alike require some payoff for intellectual work over and beyond the joy of using the mind to tackle and master problems. On the other hand, it is only the totally enslaved or dangerously famished man who ever uses his mind only for the purpose of extrinsic rewards and with no gratification in problem-solving itself. Too little extrinsic reward for problem-solving leads to a reduction of effort. The effects of too great an emphasis on extrinsic reward are either to stereotype or disrupt learning, as has already been mentioned. The concept of *an optimum balance* between the two has been in the psychological literature for nearly half a century—the Yerkes-Dodson principle—but its significance for more complex learning has been overlooked. Some degree of optimal external reward assures connected and planful behavior by imbedding the learning in a larger enterprise of goal-seeking. Less than optimum reward is the road to being a dilettante. More than optimum reward produces difficulties because the urgency it creates may lead to time pressures that restrict the amount of information processing that a human being is willing to invest enroute to a goal.

7.2.2. Studies of latent learning, where external motives are minimal, indicate that information achieved in such a state can later be organized for instrumental activity leading to specific rewards. But studies of learning under excessive drive for external reward suggest that what is lost in learning cannot be easily recovered. The asymmetry is not trivial.

7.2.3. It is often necessary in initiating learning and problem-solving in young children (and in older ones as well) to resort to an initial regimen of praise and reward for each successful act. The danger is creating dependence in the learner upon the reward and the rewarder to keep the behavior going. *Optimum phasing requires a gradual process of giving the rewarding function back to the task and the learner.* To achieve this objective requires a continuously available knowledge of results. For it is impossible for the learner to substitute satisfaction in problem-solving for external reward without continuous knowledge of how he is doing. It is a moot question how one goes about substituting a satisfying knowledge of progress for external reward even when knowledge of results is available. It is clear that in order for children to show the so-called Zeigarnik effect—working at a task for the sake of completing it—there must be some structure in the task so that they know where they are in their efforts. Torrey (1952) has shown this to be the case. Perhaps too there are techniques of reward that serve to reinforce satisfaction in the carrying out of an interesting attempt at problem-solving—even when such attempts are unsuccessful. Perhaps the secret is to reward "good errors"—i.e., errors that show insight or courage or innovation—and to withhold for banal efforts, even if they succeed. Such a regimen, used in moderation, may help emphasize process rather than product.

7.2.4. Segmentation refers to the nature and size of an act.

It is plain that a momentary response is not profitably regarded as a cognitive act—carrying a particular number over in addition or subtraction, for example. For obviously it is imbedded in some larger act that controls and regulates it. Nor, at the other extreme, can we take a decade in a person's thinking life and consider it profitably as a proper segment of behavior. It contains too many semiautonomous sub-acts. In problem-solving, the "graininess" of activity is critically important. Any intellectual "act" contains any number of little "actlets," just as the running off of a complex computer program involves thousands of minute operations by the elementary processes that make it up. But for the attainment of intellectual mastery in certain kinds of activities, certain integrated acts are of especial importance. *The most "natural" unit one can isolate in intellectual activity consists first in sensing a problem.* Sensing a problem involves the *recognition that there is a difference between where you are now and where you want to be in some task.* The child who fails to see the discrepancy between his present common-sense notion about "gravity" and the diversity of things that require more particular explanation is not yet launched into problem-solving in inertial physics. Given recognition of discrepancy, one then searches out operations or ideas or techniques appropriate for reducing it. The search for operations is guided by a problem-solver's analysis of the nature of the discrepancy. If the discrepancy is made to disappear by the application of an operation, the task is complete. In problem-solving, the course of activity from discovery of discrepancy to its removal represents what we can call a "natural unit." Any such unit is, of course, imbedded in larger scale units as well. Adequate problem-solving becomes powerful problem-solving when the imbedding of such natural units somehow matches the task. That is to say, if you are learning about the American Civil War, it does not suffice to stop with a recounting of dates, though that may have got you to the goal of clearing up chronological confusion. The chronology should lead you on to a grasp of the significance of the events involved. Determining optimum units of this kind is almost as obscure as it is important. For the determination guides not only how we construct units in a curriculum but where we provide the opportunities for success and for reward. Concretely, if there are gold stars to be passed out or grades to be distributed, let them be delayed until some meaningful segment of activity has been completed.

8. Conclusions

The chief fault of such an exercise as this is that the propositions one states are likely to be more *ad hoc* than they should be. There is surely a simpler set of propositions than these that could be stated and from which these could be derived. And even with the present set, little has been done to derive additional consequences that follow logically from what has been said. Yet it does provide something of a beginning.

There are many other detailed points about instruction that could be made in the spirit of guessing. I suspect that they should be made even though they are poorly supported by present knowledge. At least they would be explicit, which is one step on the road to being either accepted or rejected.

THE FORMATION AND DISCOVERY OF "HIGHER-ORDER" UNITS IN INTELLECTUAL TASKS

Eleanor J. Gibson

(The following outline was prepared not to answer questions, but to pose them. Some ideas are stated as propositions to be argued. If the right questions can be asked, in the right order, an experimental attack and better understanding of learning in educational situations should be facilitated.)

The Problem

How is information most efficiently processed in intellectual activities of the kind involving socially coded stimuli such as speaking and comprehension of languages, reading, reading music, all kinds of tasks involving numbers, remembering facts (e.g., history), and so on?

That there are units, and in fact optimal units, is taken for granted. That we have little knowledge about the units is also taken for granted. ("It is obvious, of course, that people have finite boundaries on what they can store both as talkers and as listeners, so language must contain some natural coding units of finite length. But what these coding units are for an articulate human being still remains a mystery." From George Miller, "Decision Units in the Perception of Speech," p. 81.)

We need to know what the optimal units for a given task are, and also how training for efficient unit structure should proceed. In other words, the question is how development proceeds with reference to unit structure.

A Little Background

1. The efficiency of "larger" units in reading was demonstrated by Cattell (1885) and corroborated afterwards by Erdmann and Dodge and many others.

2. Bryan and Harter (1897) studied the transition from "letter habits" to "word habits" in receiving and sending Morse code, and coined the term "higher units."

3. Wertheimer's laws of organization were essentially grouping principles for unit formation. Wertheimer wrote about the learning process in geometry but did not make much use of his laws.

4. Emphasis on "response-integration" in verbal learning literature by Underwood, Mandler, and others. Backers of "associative frequency."

5. Information theory returned to Cattell's original problem with a "new look," e.g., Garner's treatment of constraint as structure and structure as directly perceived; Miller's "chunks."

Some Propositions About Units

1. There are environmental, ecologically "natural" stimuli and there are symbolic, conventionally "coded" ones. Structure and order are characteristic of both, and we can therefore speak of units in both cases and of higher orders of units.

> An example of structured stimuli provided by the natural environment would be texture gradients—of coded stimuli, words. The latter are considered to be equally real and objective. The following propositions apply in some cases to both, but we are primarily concerned here with coded stimuli, since we are concerned with intellectual tasks.

2. Units vary with the task and its subject matter, and with the stages of mastery of the task.

3. Units for any task come in a *hierarchy*, from the smallest basic ones to very complex structures.

> See G. Miller, E. Galanter, and K. Pribram, *Plans and the Structure of Behavior*, New York: Henry Holt, 1960, Chapter 2, p. 21–39. They describe behavior as a hierarchy of TOTE units (test, operate, test, exit). "Thus the compound of TOTE units unravels itself simply enough into a coordinated sequence of tests and actions, although the underlying structure that organizes and coordinates the behavior is itself hierarchical, not sequential" (p. 34). They apply the notion of TOTE hierarchy to numerous kinds of behavior.
>
> See also Gagné, R. "The Acquisition of Knowledge," *Psych. Rev.*, 1962, 69, for a discussion of hierarchical structure of a mathematical task.

4. Progression of knowledge depends on transferring or "building on" from one stage to the next, with consequent shift of units. Trying to teach units of a higher level, skipping the earlier stage, will result in poor transfer to the next higher.

e.g. Teaching reading by the "whole word," "look-see" method yields poor transfer and, consequently, slow readers.

5. Smaller units are *not* necessarily atomic components of the larger ones, even though there is progression by stages.

e.g. Gramatical structure is not a synthesis of morphemes.

6. The learning process and the perceptual process may be different, depending on the level in the hierarchy.

e.g. Perceptual learning at the letter stage, or code item stage, is typically discriminatory; but spelling patterns are probably discovered (induced and generalized).

Fleishman and Fruchter ("Factor Structure and Predictability of Successive Stages of Learning Morse Code," *J. Appl. Psychol.*, 1960, 44) found different factor loadings at different stages of learning Morse code.

Or note Miller *et al.*, (Plans, p. 91), "development of a skill has an effect similar to providing a digital-to-analogue converter on the output of a digital computing machine."

7. In any useful intellectual task there is *intrinsic* structure (a unique internal structure which can be objectively defined). This intrinsic structure, be it axioms, grammar, correspondence rules, scales, or whatever, determines or defines units at various levels. (These may be what Bruner calls "natural" units. They are natural only in the sense that they are determined by the superstructure; they are not natural in the same sense that faces, textures, etc. are.) A distinction can be made between intrinsic units (defined by the superstructure) and artificial or arbitrary units.

8. In a senseless task, where there are no intrinsic units, the learner will tend to *impose* structure on material given him to perceive, identify, or remember.

e.g., perception under impoverished conditions, memorizing nonsense syllables, inventing memory systems for telephone numbers, jingles as memory devices, etc.

9. Imposed or arbitrary structure will inhibit transfer to more advanced levels in a task which has intrinsic structure. Therefore, the identification of the unit structure of a task is a crucial problem for educational psychology.

10. As learning theorists asking how a "higher-order" unit is developed, we can speak of "grouping principles" (We have chosen this term as a neutral one.) Some principles which have been or should be considered are:

a. Associative frequency (and sequential probability). See Mandler, G. "From Association to Structure," *Psychol. Rev.*, 1962, 69, and Wallach, M., "Perceptual Recognition of Approximations to English in Relation to Spelling Achievement," *J. Educ. Psychol.*, 1963, 54. (This principle derives most of its backing from research on senseless tasks. Note that sequential probability is a kind of regularity present objectively and could, therefore, be discovered or detected. See Bruner, Wallach, and Galanter, "The Identification of Recurrent Regularity," *Amer. J. Psychol.*, 1959, 72.)

b. Meaning has never been satisfactorily defined as a learning principle, but it is nevertheless often assumed to be a grouping or organizing principle. The earlier research on word units (Cattell and others) assumed that meaningfulness of the word explained its unity. Learning theorists are often inclined to reduce meaning to associative frequency.

c. Cross-modal correspondences and cross-modal transfer, e.g., in reading, and in reading music.

See Gibson, Pick, Osser, and Hammond, "The Role of Grapheme-Phoneme Correspondences in the Recognition of Words," *Amer. J. Psychol.*, 1962;

Also, Gibson, Bishop, Schiff, and Smith, "A Comparison of Meaning and Pronunciability in the Perception and Retention of Verbal Material" (EPA paper, 1963).

d. Structural redundancies, regularities, constraints.

Wertheimer's laws of organization might be examples of these. But Garner's treatment of constraints as structure which is directly perceived is a more modern conception. Garner finds that some structures are more easily learned or perceived or recalled than others.

Grammar and syntax probably come in here.

What about logic?

11. A decision about the best grouping principles for a subject learning a given task depends on the task and its intrinsic structure.

e.g. Note the variable effects of meaning in perceiving and recalling.

12. When there is well-defined intrinsic structure, and regularity (rules) to be mastered, the learner should be given the opportunity to induce (discover) them, with the expectation that appropriate units will be generated.

13. The learner can be helped to induce patterns of structure by enhancement of distinctive features of the structure, and by contrast.

14. Best transfer to the next stage in the hierarchy of the task folows self-discovery. (See research on value of discovery.)

15. Development within the task hierarchy might be thought of as a compounding of units at one stage with a sort of "emergent evolution" of new units at the next, or it might be thought of as differentiation of the top stage, the complex message, into its structural layers. This question may be merely a philosophical one; but it just might be of importance for education. The fact that a prob-

lem solver must be able to recognize the right answer when he reaches it, or that a music student makes no progress if he hasn't heard music may be relevant. There might be layers of complexity within which differentiation occurs. A *beginning* music student needn't have heard a symphony to make progress, but at a later stage he must have.

CHILD-REARING ANTECEDENTS OF COGNITIVE BEHAVIOR

Harry Levin

In comparison with the vast amount of research on the familial antecedents of such motivational systems as aggression, dependency, and achievement, there is an amazing dearth of research on the precursors of cognitive behavior. Of course, in order to make this statement we have to summarily write out of hand a substantial body of information on the correlates of intelligence test scores or school achievement. There do exist some consistent findings on the relationships between social structure variables (usually social class or education of parents) or birth order of the child and his intelligence test scores. The nature of the correlations are obvious. These data could in a sense be helpful since they point to categories of variables with which we might concern ourselves. However, both social class, for example, and overall intelligence test scores are such a mélange of variables that I doubt whether they will add to a precise definition of our problem.

There have been a few old straws in the wind and currently there are several important studies which we must take account of. Levy's familiar finding that overprotected boys are verbally facile and poor in arithmetic is an intriguing lead. Witkin's metaphor that dependent childern also exhibit perceptual field dependency is also provocative.

I shall cite several studies that point to directions we may profitably follow. Eleanor Maccoby's excellent research on Differential Cognitive Abilities includes a study by Bing on the child-rearing antecedents of differential abilities. She found that hypotheses based on uncomplicated generalization from the home to the test (more of this later) were generally confirmed. For example, parents who directly rewarded verbal behavior in their children created children high on verbal as compared to numerical or spatial ability. However, she reports that witholding verbal interaction also relates to high verbal ability, a finding which is reminiscent of Brown's report that children advance in grammatical complexity when their rudimentary forms are no longer tolerated by their mothers.

As a source of leads for research on the antecedents of cognitive behavior, I have been most excited by Robert's work on games. Both cross-culturally and within our culture he finds relationships such as "reinforcement for obedience is related to high incidence of games of strategy." At this point such a finding may be interpreted in terms of creating a preference for these games or in terms of the skills for such games. This distinction may only be reasonable logically.

What is the gem of existing research that I was looking for? The ideal paradigm would be a study in which some specific cognitive behavior, such as abstraction from a set of instances, or degree of scanning alternatives during problem-solving, or the application of a succession of solutions was isolated. Given the categorization of children on the basis of one or more of these behaviors, we may ask what were his experiences before starting school. The remainder of this paper will be concerned with the assumptions of and suggested procedures for such research.

A Theory of Instruction in the Home

A theory of instruction is just as necessary for studying the child's cognitive habits or dispositions as it is for guiding instruction in school. I honestly do not believe that we can expect to do sophisticated research on the child-rearing antecedents of cognition independently of a theory of instruction. Rather, it would be useful to apply the same theory of instruction to both learning in the home and in school, even granting the values of some of the parameters may differ, and there may indeed be some variables present in one part of the theory that will not be useful in the other. For example, the home-school theories may vary in the following respects:

1. The nature of the relationship between the tutors in the home and the learner is different from his relationship to his teachers in school. The greater intensity of the personal relationships and the involvement of the child with his parents are obvious. We can profitably ask, I believe, for data on the relationship between degree of emotional attachment to the teacher and the efficiency of learning. Hartup's study provides a guideline here.
2. The mother spends more time with the child, at least before the school years, than does any teacher thereafter.
3. The tutors in the home are responsible for a wide variety of behaviors compared to the restricted subject matter with which the teacher is concerned.
4. The programing of success and failure, rewards and punish-

ments, is undoubtedly more haphazard in the home than it need be in the classroom.

5. The criteria for successful achievement are more clear in the school than in the home.
6. The variety of teachers concerned simultaneously with the same learning is greater in the home than in the classroom.
7. It may be that for certain learnings the child is more docile during his preschool years and for others is more permeable when he is in school.
8. School behavior occurs in a peer context which, depending on the composition of the family, is less true in the home.

We could go on listing these differences, but I question how many of the obvious contrasts are relevant for a theory of instruction.

I don't think there is a curriculum for child-rearing. If we think how many behaviors the mother groups into the same category for similar treatment and how haphazard are the consequences of the child's actions, we might wonder how he develops any consistency in his behavior. Certainly, no existing theory of learning can find its way in this jungle.

Assumptions in Child-Rearing Research

1. At the basis of any research on the consequences of child-rearing experiences is some more or less explicit theory of generalization. The child's aggression in doll play, to take a common example, is supposed to be related in some complicated way to his experiences in the home. The dolls are effigies of his parents. To take another really farfetched example, a child who draws pictures around the border of a piece of paper is reflecting the depth of his dependency on his parents presumably because there is some system mediating the generalization between his parent as someone he can physically lean against and the edge of the paper as providing the environmental definition. Likewise, as we build a theory of generalization about the antecedents of cognitive behaviors, we will make certain assumptions about physical or response-mediated similarities between the antecedent and the test situations.
2. Behavior which is *directly* reinforced in the home will also be appropriately manifested in the test (classroom, perhaps) situation. Maccoby found that the best predictor of verbal facility is the reinforcement of verbal behavior by the parents. The assumption we have to make in this straightforward postulate is that there is sufficient similarity between the two situations in which the child behaves verbally.

3. This and the next model of generalization employ incidental learning assumptions. Suppose that the parent reinforces verbal aggression in a variety of situations. We assume, although I could wish the literature even on this point would be clearer, that the child learns something about shouting and calling names. However, what does he learn about verbality? If there is a contrast between the negative reinforcement of physical aggression and positive reinforcement of verbal aggression so that we have ideal conditions for inducing generalization, does he *incidentally* increase his verbality? Maccoby's data indicate that this is not the case. Probably, the circumstances in such instances are not appropriate for incidental learning because of the complete involvement with the strong emotional aspects of aggressiveness training. Do we know whether emotionally charged incidents yield less incidental learning than do more neutral experiences?
4. This model depends on a combination of incidental learning, and abstraction of and generalization of a principle. Suppose a parent met many of his child's requests, and statements with "Why?" We might predict that this child, anticipating the inevitable parental query, would begin his problem-solving with the formation of explicit hypotheses. An analogue in the child-rearing antecedents of behavior would be a child who in a variety of situations is reinforced for compliance and who might then form the implicit generalization that effective interpersonal relationships are formed on the basis of compliance.

In the above assumptions, we are asking a lot of explanatory leverage from ephemeral learning experiences. Each of them rather than being postulational may well be a fount of empirical hypotheses. Nevertheless, I would venture to say that a theory of cognitive socialization would also use the same underpinnings. Strategically, we may ask whether it would be worthwhile to test the assumptions or to bypass them in favor of immediate work on the larger antecedent-consequent problems.

Research Strategy

The research on the child-rearing antecedents of motivational systems was impelled by Freudian theory and its behavior theory adumbrations. This meant that, for good or ill, the researchers had a ready-made lexicon of variables as well as notions about how the variables interrelate. The theory postulated that the consequences of early experiences were generally personality characteristics presumably so pervasive that they would exhibit themselves in a range of situations. Consequently, researchers paid little attention to the nature of the instigating situations in which they measured aggression, dependency, etc. It is as though the child were more or less aggressive, independent of the instigating situations. As an aside I would suggest that one way to clarify the research on the antecedents of personality characteristics would be to look at the situations in which the consequent measures were obtained.

There are no theories of cognitive development, except perhaps Piaget's, to play the role that Freudian theory did for other developmental problems. Moreover, the assumption that we could study some child-rearing antecedents of thinking and problem-solving independent of the problems is foolish. I am suggesting that we need careful definitions of cognitive behaviors which, for our purpose, should be related to the behaviors exhibited in school performance.

Further, knowledge of child-rearing antecedents becomes useful only in those cases where children exhibit individual differences in their cognitive behaviors. Let me give an example. Since exploration of a problem is a function of the novelty of the problem and if increasingly novel stimuli are introduced to the child, we expect that his commerce with the stimuli will increase. Let us assume (unrealistically) that 90 percent of the variance of exploration is accounted for by the nature of the problems presented to the child. Concern with child-rearing variables would be a waste of time. Only insofar as there remains unaccounted-for variance after the stimulus manipulation can we profitably add variables of child-rearing, intelligence, personality, etc., to our predictions. A perfect theory of instruction would account for learning solely in terms of the problem situations presented to the child.

Strategy of research on these problems can be bold or timid. I lean toward the timid. This would mean as a first step the naturalistic observation of classroom learning behavior. Then, we could look at the situational determinants of variations in some of these behaviors. We have a choice of working at this stage in the classroom or purifying the processes in the laboratory. To some extent this choice is a matter of taste and is a function of how well we seem to understand the cognitive processes. The play between the laboratory and the classroom could be profitable. Only after we are sure we understand the process and have accounted for as much variation with the limited manipulable variables would I suggest that we be concerned about other determinants. It is a truism that these determinants will include capacity and personality variables. The child-rearing predictors may be related in two ways: (1) a direct relation between childhood experiences and cognitive behavior; (2) relationships which go from child-rearing antecedents to personality dispositions to cognitive behavior. One of Bruner's examples is relevant. The child who has been severely punished for failure may show predictable cognitive processes which would be most sensibly interpreted in terms of fear rather than in terms of characteristic skills in problem-solving.

In summary, I would strongly urge that the first step be a taxonomy of education-related learning. I have a hobbyhorse that I would like to see implemented. Let's take a small number of classrooms, preferably first grades, whose teachers are bright, receptive, and experimental. In each of these rooms we could put a graduate student in psychology and a graduate student in linguistics to form a research team with the teacher. Their tasks would be many but primarily they would observe and record the goings on in the classroom. They would try to justify procedures in terms of theory. They would continually devise materials and procedures to try out with the children. They would carry out a number of experiments every day. The outcome of these studies would be a detailed description of the happenings in the classroom in terms of at least implicit theories about learning and language. We would have a large number of pretests for more elaborate research and development projects. We might even have some notions about the home variables for various kinds of learners. After these explorations, there would be research projects which clarified the learning variables and finally, to get to our main purposes, we would study the child-rearing antecedents of these behaviors. If this procedure makes sense, how do we go about setting up some research classes?

NOTES ON A FORMALISM OF COGNITIVE OPERATIONS AND TASK DESCRIPTION

Lloyd Morrisett

These notes are concerned with "thinking" that can be characterized in the paradigm of a problem, i.e. where, for purposes of analysis, it is possible to enumerate some starting points, or "givens," and then state what a solution will be like. The problem is to find a set of cognitive operations that move from the starting point to a possible solution. In these terms I include things from a specific mathematical problem, the solution of an algebraic equation, to creating a painting. For mathematics: $3 \times 3 = ?$ Given the starting point, the problem is to write down a number which satisfies certain criteria. For chess: given the state of the board, make a legal move which also improves your position. For painting: given a blank canvas, form a brush stroke which will be part of a completed picture.

Let the term "action space" characterize the universe of elements (objects) which form the problem and in which a solution can occur: in the arithmetic problem the universe of numbers in the person's repertoire; in the chess problem, the universe of possible moves; in the painting example, the universe of brush strokes. In general, action space is characterized by strong temporal and spatial constraints, particularly in those cases where problem-solution requires some rearrangement of the physical environment or your relationship to it. In this conceptual analysis an action space is characterized by n dimensions sufficient to uniquely identify all possible combinations of elements in the universe, and a point in action space represents one arrangement or combination of elements. A problem-solution is achieved by moving from the starting point through a set of intermediate points to a solution point. Assuming the spatial and temporal constraints of the physical world: (1) exploration in the action space may be irreversible, (2) exploration in the action space may be risky or dangerous, (3) exploration in the action space may be costly in terms of energy, and (4) exploration in the action space may have a very small probability of success because of the very large number of combinations of possible moves.

Throughout this analysis it is assumed that each actor has a memory and some means of acquiring information and storing it, although I am not directly concerned with acquisition and storage. Let a part of memory be associated with action space. If this memory is blank then solutions can occur in action space but only by trial and error—trial and error not being random but constrained by the characteristics of the space. If the memory is not blank it can contain rules which guide moves in the action space and increase the probability of solution. At one extreme the rule might be a list of moves and at the other an algorithm which can be applied to guarantee solution.

Let the term "description space" characterize a universe of symbols which (1) can be used to form a complete description of an action space, and (2) can be used to make this description public. A point within description space bears a one-to-one correspondence to a point within action space, but the dimensions of description space are not spatial and temporal, or at least only weakly so, and are principally derived from conventionally agreed upon definitions and laws. Thus, in description space, explorations may be reversible and are typically less dangerous, risky, and wasteful of energy. Description space does conserve the universe of possible moves in action space, but the combination of moves is typically reordered. Again, a portion of memory is assigned to description space and solutions can occur in description space by (1) trial and error, (2) the application of lists, rules, and algorithms from memory.

One of the main tasks of education is to provide description spaces—language, mathematics, geometries, maps—and an associated set of rules.

Finally, distinguish "heuristic space," which is conceived of as a universe of elements constituting a partial description, not necessarily in publicly available symbols, of either action space and/or description space. By a partial description is meant that the elements of heuristic space are not necessarily or typically in a one-to-one relation to the elements of action space or description space. Heuristic space may be thought of as a private language. In general, heuristic space does not conserve the universe of possible moves in action or description space; rather it functions to radically reduce the possible moves and it also admits of combinations of moves which are impossible or unlikely in action or description space.

At this point it will be obvious that these definitions are relative and may overlap. For example, in problems of mathematics, action and description spaces are largely coincident. Also, the definitions are relative. From the point of view of an adult, the child's language conforms more closely to the definition of heuristic space than to description space. Learning transforms language into a description space. A schematic notion of these distinctions follows:

Heuristic Space
1. Private

Intuition
Intuition

Analysis

Action Space
1. Real world

Description Space
1. Symbolic
2. Public
3. Conventional

Only one implication of this characterization of cognitive operation will be mentioned, but it has important educational outcomes. The argument is advanced that optimally effective thinking will take place when the individual has at his command both operations within a well-developed description space and within a well-developed heuristic space. Since these, in most cases, are linked, teaching should proceed to simultaneously encourage the development of both sets of operations and at the same time lead the individual to be able to discriminate between the two. This also implies that most heuristic operations will be jointly defined by a thorough understanding of action space and description space, i.e., most useful heuristics can be expected to develop out of intimate acquaintance with a given subject matter. Since heuristic space may, at least in part, be private, teaching heuristic operations is not easily accomplished. Problems and solutions can be defined and individuals encouraged to seek their own means of solution. Training can be given in analogy, metaphor, and symbolism relevant to the subject matter. If this is to be effective, however, then training should be an integral part of the more direct attention to teaching descriptive operations. Problems which the individual cannot solve by available descriptive techniques, i.e., known rules and algorithms, should be included in the curriculum along with "practice exercises." The case is here made that these problems have not only motivational value but are such as to require heuristic thinking.

TOWARDS A BEHAVIORAL PSYCHOLOGY OF MATHEMATICAL THINKING

Patrick Suppes

Some fundamental concepts that stand uncertainly on the border of mathematics, philosophy, and psychology are explored in this paper. What I have to say is not yet fully worked out, and I must ask the reader's indulgence of its preliminary character. On the other hand, if the direction in which the ideas in this paper are moving is correct, then what I have to say does, I think, have some direct significance for attitudes towards the teaching of mathematics.

There are five main ideas in this paper, discussed in the following order: the rather vague concept of *abstraction*, much used but seldom defined by mathematicians; the related topic of *imagery* in mathematical thinking; the *psychological nature of mathematical objects;* the nature of *meaning in arithmetic*, particularly as reflected in the beginning experience of children; and finally, the psychology of *algorithms in arithmetic.*

Abstraction

Some mathematicians say that the concept of set is too abstract to furnish an appropriate place for the elementary-school child to begin work in mathematics. Such a statement, I think, results from confusion about the meaning of *abstract* in mathematics. It has long been customary, although probably less so now than previously, to talk about abstract set theory or abstract group theory. To a psychologist or philosopher concerned with the nature of mathematics, it is natural to ask, What is the meaning of "abstract" in these contexts? There is, I think, more than one answer to this query. One answer is that "abstract" often means something very close to "general," and the meaning of "general" is that the class of models of the theory has been considerably enlarged. The notion of abstractness comes in because the class of models is now so large that any simple imagery or picture of a typical model is not possible. The range of models is too diverse.

In group theory, for example, one intuitive basis was the particular case of groups of transformations. In fact, the very justification of the postulates of group theory is often given in terms of Cayley's theorem, which states that every group is isomorphic to a group of transformations. It may be rightly maintained that the "basic" properties of groups of transformations have been correctly abstracted in the abstract version of the axioms, just because we are able to prove Cayley's theorem. So we can see that another sense of *abstract*, closely related to the first, is that certain intuitive and perhaps often complex properties of the original objects of the theory have been dropped, as in the case of groups, sets of natural numbers, or sets of real numbers, and we are now prepared to talk about objects satisfying the theory which may have a much simpler internal structure. This meaning of *abstract*, it may be noted, is very close to the etymological meaning.

Under still another, closely related sense of the term, a theory is called "abstract" when there is no one highly suggestive model of the theory that most people think of when the theory is mentioned. In this sense, for example, Euclidean plane geometry is not abstract, because we all immediately begin to think of figures drawn on the blackboard as an approximate physical model of the theory. In the case of group theory the situation is different. It would indeed be interesting to ask a wide range of mathematicians what is called to mind or what imagery is evoked when they read or think about, let us say, the associative axiom for groups or the axiom on the existence of an inverse? Or what sort of stimulus associations or imagery do they have in thinking about the axiom of infinity in set theory? It is my own suspicion that the combinatorial, formalist way of thinking is much more prevalent than many people would like to admit. Many mathematicians, particularly those with an algebraic tendency, have as the immediate sort of stimulus imagery the mathematical symbols themselves and think very much in terms of recombining and manipulating these symbols. In any case, knowledge of the distribution of imagery among mathematicians need not be available in order to make sense out of the presentation of simple notions like that of a set to elementary school children. The reason for this, I think, is the following.

The very character of a theory that is said to make it "abstract," in the sense of admitting a wide diversity of models, also permits an introduction to the theory in terms of extremely simple and concrete illustrations. This is particularly true of set theory. No doubt a case can be made to the effect that the general notion of set, particularly when one wishes to think of sets of high cardinality, is a difficult thing from an intuitive standpoint. This is certainly not the case when one is thinking of sets of a small finite number of elements. In introducing the child to the concept of set, we may give the most concrete and everyday sorts of examples. Objects may be picked up in the environment surrounding him, and he may be told that these constitute a collection, a family, or a set of things. This simple set of things is a good deal more concrete and vivid to him than the much more devious notion of number. Using, in fact, the distinctions given above, we can see that in one sense the notion of number is clearly more abstract than the notion of set; for twoness, for example, is a property of many diverse sets, and any particular set that has the property of twoness is more concrete and less abstract than twoness itself. By taking the next step and introducing explicit operations and notation for operations on sets, we can easily proceed to develop mathematical laws very close to those of arithmetic, but at a more concrete level. I have in mind particularly the union of disjoint sets and difference of sets, where the set which is taken away is a subset of the original set. The operation of union, thus restricted, is a complete concrete analog of addition, and the operation of difference of sets an analog of subtraction. I won't say a lot more about these matters, for I have written about them extensively elsewhere. The point of the present discussion is to emphasize that one must distinguish clearly between an abstract theory and the degree of abstractness of any particular model of that theory. I shall have more to say about abstraction in the next section dealing with imagery.

Imagery

Mathematicians classify each other as primarily geometers, algebraists, or analysts. The contrast between the geometers and algebraists is particularly clear in folklore conversations about imagery. The folklore version is that the geometers tend to think in terms of visual geometrical images and the algebraists in terms of combinations of symbols. I do not know to what extent this is really true, but it would be interesting indeed to have a more thorough body of data on the matter. To begin with, it would be desirable to have some of the simple association data which exist in such abundance in the experimental literature of verbal learning. Such association data would be an interesting supplement to the kind of thing discussed and reviewed in Hadamard's little book on the psychology of mathematics.

I tend to think of the concepts of imagery and abstraction as closely related. I could in fact see attempting to push a definition of abstraction as the measure of the diversity of imagery produced by a standard body of mathematics and stimulus material in a given population. I am not yet prepared, however, to push any particular systematic definition of abstraction. There are many preliminaries yet to be clarified.

As one kind of investigation connected with imagery in abstraction, the following sort of modification of the standard association experiment is of considerable interest. With a standard body of mathematical material we would set students to work proving theorems from the axioms of different mathematical systems. It would, of course, be interesting to take axioms from different domains, for example, to compare Euclidean geometry and group theory. As the subjects proceeded to prove theorems we would at each step ask for their associations. Two sorts of questions would be of immediate interest. What is the primary character of the associations given? Secondly, what kinds of dependence exist between the association given at different stages in the proof of a given theorem, or in proofs of successive theorems of a given system? As far as I know, no investigations of this sort have yet been conducted, although some of the members of this conference may indeed have references to the literature that will demonstrate my ignorance. On the other hand, such experiments should not be difficult to perform and the results might be of interest.

There is one aspect of such experiments that I am not yet clear on how to handle. I have in mind the kind of thing that may arise with respect to a system like the axioms for group theory. When I use the phrase associative axiom, the association I have (not to make a pun) is just of the axiom itself written in the folowing form.

$$xo(yoz) = (xoy)oz$$

In other words, my association to the concept of associativity or to the words "associative axiom" is just a symbolic formulation itself of the property of associativity. It would be important in any investigation of associations in mathematical contexts to design the experiment in such a way as to permit this sort of association as an answer. I find these associations very prevalent in my own thinking, but I know from conversations with several mathematicians that there are rather strong differences in these matters. Let me give just one or two other personal examples as illustrations of the kind of thing I think would be desirable to pursue systematically. When I think of the general quadratic equation

$$ax^2 + bx + c = 0$$

my most direct and immediate association is the standard way of writing the solution of this equation:

$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}.$$

On the other hand, when I mention certain geometrical notions my associations are not so verbal or symbol-oriented. For example, when I think of three points, I associate immediately to an equilateral triangle, whose sides I subjectively think of as being about 1½ inches in length. On the other hand, as I think of this triangle I also tend to add immediately after the symbol of the triangle the phrase "noncollinear" and what is interesting is that the condition of noncollinearity is not represented by a geometrical image, but by the word.

I have undoubtedly described too simply the associations that subjects might have at each stage of writing down a mathematical proof. The main problem is to distinguish between associations that play an essential and important role in obtaining the proof, and those which are more or less accidental accompaniments of finding the proof. For example, a person may read a theorem about geometry, written in English words, and as he begins to search for a proof of this theorem, he associates to simple geometrical figures—in particular, to the sort of figure useful for setting up the conditions of the theorem. At the same time that he has this geometrical association, or if he goes through the process of drawing such a figure, he may be having associations about his wife, his mother, or his children, etc. We would not want to think of these latter associations as playing the same sort of role in finding the proof. In other words, we want to see to what extent a chain of associations may be identified, a chain that is critical for the heuristic steps of finding a proof. It is also important, I am sure, to separate the geometrical kind of case from the other extreme—as a pure case, the kind of thinking that goes on when one is playing a game like chess or checkers. What kind of associations are crucial for finding a good move in chess, checkers, or, to pick a different sort of example, bridge?

An experiment we have conducted in our laboratories has some bearing on the matters I am discussing. This experiment concerned the possible differences between learning rules of logical inference in a purely formal way or as part of ordinary English. The three rules studied were:

$$\begin{array}{ccc} \text{Det} & \text{Sim} & \text{Com} \\[4pt] \dfrac{\begin{array}{c}P \rightarrow Q\\ P\end{array}}{Q} & \dfrac{P \wedge Q}{P} & \dfrac{P \wedge Q}{Q \wedge P} \end{array}$$

Group 1 received the formal part first (FA) and then the interpreted logic in ordinary English (IB). Group 2 reversed this order: IA, then FB. Note that I use A for the early part of the experiment and B for the later part. Schematically then:

Group 1 FA + IB
Group 2 IA + FB

The formal (F) and interpreted (I) parts of the experiment were formally isomorphic.

Some of the results are shown in tables 1 and 2. The subjects were fourth-graders with an IQ range of 110 to 131; there were 24 subjects in each group.

Table 1.—Comparisons of errors on different parts of logic experiment

Comparison	t	df	Significance
$\mathrm{FA} > \mathrm{FB}$	1.94	46	.1
$\mathrm{IA} > \mathrm{IB}$	3.28	46	.01
$\mathrm{FA} \neq \mathrm{IA}$	1.47	46	-----------
$\mathrm{FB} \neq \mathrm{IB}$	.08	46	-----------
$\mathrm{FA} + \mathrm{FB} \neq \mathrm{IA} + \mathrm{IB}$	1.15	94	-----------
$\mathrm{FA} + \mathrm{IB} \neq \mathrm{IA} + \mathrm{FB}$	1.07	94	-----------

Table 2.—Vincent learning curves in quartiles for logic experiment

Group	Probability of error in each quartile			
	1	2	3	4
FA	.40	.36	.39	.24
IB	.32	.32	.30	.19
IA	.48	.41	.33	.28
FB	.21	.21	.28	.14

Perusal of tables 1 and 2 indicates that the order of presentation, formal material first or last, does not radically affect learning. There is, however, some evidence in the mean trials of last error that there was positive transfer from one part of the experiment to the other for both groups. For example, the group that began with the formal material had a mean trial of last error of 14.1 on this part, but the group that received this material later had a smaller mean trial of last error of 10.9. In the case of the interpreted part, the group beginning with it had a mean trial of last error of 18.3, but the group that received this material after the formal part had a mean trial of last error of 7.7, a very considerable reduction. Now, one way of measuring the amount of transfer from one concept or presentation of mathematical material to a second is to consider the average mean trial of last error for both concepts in the two possible orders. If we look at the logic experiment from this standpoint, there is a significant difference between the group beginning with the formal material, completely uninterpreted as to meaning, and the group beginning with the interpreted material. The average trial of last error on both parts of the experiment for the group beginning on the formal part is 10.9 and for the group beginning on the interpreted part is 14.6. In a very tentative way these results favor an order of learning of mathematical concepts not yet widely explored in curriculum experiments.

Psychological Nature of Mathematical Objects

A proper psychology of mathematical thinking should throw new light on old controversies about the nature of mathematical objects. The three classical positions on the foundations of mathematics in the 20th century characteristically differ in their conception of the nature of mathematical objects. Intuitionism holds that in the most fundamental sense mathematical objects are themselves thoughts or "ideas." As Heyting puts it, the subject of intuitionism is "constructive mathematical thought." For the intuitionist the formalization of mathematical theory can never be certain of expressing correctly the mathematics. Mathematical thoughts, not the formalization, are the primary objects of mathematics.

The view of mathematical objects adopted by the formalists is quite the opposite. According to an often quoted remark of Hilbert (at least I believe this remark is due to Hilbert), formalism adopts the view that mathematics is primarily concerned with the manipulation of marks on paper. In other words, the primary subject matter of mathematics is the language in which mathematics is written, and it is for this reason that formalism goes by the name of "formalism."

The third characteristic view of mathematical objects is the Platonistic one: that mathematical objects are abstract objects existing independently of human thought or activity. Those who hold that set theory provides an appropriate foundation for mathematics usually adopt some form of Platonism in their basic attitude toward mathematical objects.

In spite of the apparent diversity of these three conceptions of mathematical objects, there is a fantastically high degree of agreement about the validity of any carefully done piece of mathematics. The intuitionists will not always necessarily accept as valid a classical proof of a mathematical theorem, but the intuitionists will, in general, always agree with the classicist on whether the theorem follows according to classical principles of construction or inference.

There is a highly invariant content of mathematics recognized by all mathematicians, including those concerned with foundations of mathematics, which is absolutely untouched by quite radically different views of the nature of mathematical objects. It is also clear that the standard philosophical methods for discussing the nature of mathematical objects do not provide appropriate tools for characterizing this invariant content.

The attitude that philosophical discussions of the nature of mathematical objects are, from a mathematical standpoint, somehow not serious is well expressed in the following quotation from a paper entitled "Nominalistic Analysis of Mathematical Language" by Leon Henkin (in *Logic, Methodology and Philosophy of Science, Proceedings of the 1960 International Congress*, Stanford University Press, 1962):

> In a congress where logic and methodology play so prominent a role, it is perhaps permissible to preface one's talk with a brief meta-talk and even to indulge in a modicum of self-reference.
>
> Let me begin, then, by confessing that, although from the beginning of my studies in logic I have been intrigued by philosophical questions concerning the foundations of mathematics, and have often been to a greater or lesser extent attracted or antagonized by some particular viewpoint, I have never felt an overwhelming compulsion to decide that any given theory was "right" or "wrong." On the contrary, I have had a strong continuing feeling that "working mathematics" comes first, and that differing approaches to the foundations of the subject were largely equally possible ways of looking at a fascinating activity and relating it to broader areas of experience.
>
> My interest in foundational theories has rather been directed toward the extent to which these are themselves susceptible of mathematical formulation, and toward the solution of technical problems which may arise from such analyses. In particular, this has characterized my approach to modern efforts to obtain a nominalistic interpretation of mathematical language.

The question posed by an attitude like that expressed by Henkin is, whether it is possible to characterize in a psychological way the activity of the working mathematician. Although I have entitled this section "Psychological Nature of Mathematical Objects," what I mean to suggest is that the classical philosophical discussions of the nature of mathematical objects may fruitfully be replaced by a concentration, not on mathematical objects, but on the character of mathematical thinking. It is, I think, by a concentration on mathematical thinking, or activity, that we can be led to characterize the invariant content of mathematics or, to use Henkin's phrase, to get at the nature of working mathematics without commitment to a particular philosophical doctrine.

By a concentration on mathematical thinking, as opposed to the nature of mathematical objects, new kinds of clarification about the nature of mathematics seem possible. Concentration on mathematical thinking is the proper emphasis for those concerned with understanding how mathematics is learned or how it should be taught. In my own work in elementary-school mathematics, I have been struck by the tension in my own thinking between the use on the one hand of classical mathematical language to describe the mathematics we are teaching—the ordinary mathematical talk about sets, numbers, binary operations on numbers, and the serious and systematic application of the language of learning theory to the analysis of what the child is learning in acquiring mathematical knowledge. Looked at from a learning-theoretic standpoint, the mathematical language has a scholastic ring about it. What I say, in fact, to my psychological friends is that what seems to be from a psychological standpoint the important thing about the kind of program I have worked on in elementary school mathematics is that the children are becoming tremendously sophisticated in using a new language. From a psychological standpoint, this ability to use the symbolic language of mathematics in an accurate and facile way is much more fundamental than learning talk about sets or learning constructive algorithms for performing operations on numbers. If this is right, then a good deal of what most of us, including myself, have to say about the learning of mathematics is itself written in the wrong kind of language. The difficult thing is that I do not yet see clearly what the right sort of language or conceptual framework is.

THE PSYCHOLOGY OF ARITHMETIC[9]

Patrick Suppes

The psychological aspects of arithmetic I want to discuss I shall place under four main headings. I do not think that these four headings are particularly the best four. Certainly they are neither exhaustive nor mutually exclusive. I will use them for purposes of somewhat arbitrary classification. I shall begin with problems of meaning in arithmetic; then turn to the psychology of algorithms; followed by discussion of problems of the sequence in which concepts should be introduced; and I end with a discussion of what behavioral account is to be given of the function of responses that correspond in ordinary talk to giving reasons for an answer.

Meaning in Arithmetic

It seems natural to say that the first problem of meaning in arithmetic is to provide an analysis of that fragment of arithmetical language which the child already possesses when he enters school.

The emphasis in the discussion of children's language by linguists in recent years has been almost entirely on the grammar of their language, but it is fair to say that the analysis of the grammar of the child's use of quantitative terms like "one" or "two" does not take us very far in attempting to understand what the child knows about arithmetic as he enters school. All of us are impressed by what the linguists have shown us about the ability of children to make grammatical transformations of a startlingly complex nature even at the age of 3 or 4 years. I am sure we shall be equally impressed with what they are able to show about the child's grasp of the semantics of his language when they turn to this problem as well. I suppose that what I want to say is that it is just as surprising that children learn the meaning of verbs as it is that they learn such things as how to transform from the active to the passive voice.

Many children who enter the first grade without any explicit training in arithmetic in kindergarten or nursery school are able to count at least to 6 or 7. To say that they are able to count to 6 or 7 does not really tell us what the counting words mean to the children. A deeper and more precise specification of this meaning seems to be an appropriate problem for additional research.

---

[9] This is a preliminary draft of the first two parts of this paper. I intend for the final version to be combined with my earlier working paper, "Towards a Behavioral Psychology of Mathematical Thinking."

It will be useful to examine one sort of example in more detail in order to indicate some of the problems involved. To begin with, many children between the ages of 4 and 5 years learn the names of numbers used in counting from 1 to 6 or 7, and are able to repeat these names verbally in the right sequence with considerable ease. Often they are able to do this before they are able to count a set of cardinality 6 or 7. On the simple supposition that they first learn the names of the numbers and how to recite them in sequence, we might be inclined to accept the hypothesis that the number names are first learned primarily as ordinal counting names, and only later as names for the cardinal numbers of sets. Unfortunately, any such simple theory of the acquisition of the meaning of the number names is not correct. It is a commonly observed phenomenon that 4-year-old children who are not yet able or who do not yet seem to know how to reproduce the number name "four" will tell you that the cardinality of a set of four objects is "two and two," or that the cardinality of a set of five objects is "three and two." It would, I think, be a useful enterprise to attempt to infer the kind of meaning children attach to number names by a detailed examination of the uses of these number names in their preschool language.

Algorithms in Arithmetic

As an initial model for thinking about algorithms, I would like to propose the following. We have in mind a given collection of problems that we wish the child to be able to solve. To make our anaysis definite at this point, let us consider a set of arithmetical problems. They might be in the form of $8 - 5 = \underline{\quad}$, $8 + \underline{\quad} = 10$, $10 - \underline{\quad} = 4$, $\underline{\quad} - 3 = 5$, etc. The machinery needed to solve these problems can be roughly divided into two parts. One part consists of direct storage in memory of certain elementary facts. Exactly what these elementary facts are will vary from stage to stage in the curriculum. Towards the beginning of arithmetic, it might consist of storage of the elementary addition facts: $1 + 1 = 2$, $1 + 2 = 3$, $2 + 1 = 3$, $1 + 0 = 1$, $2 + 0 = 2$, $3 + 0 = 3$, $0 + 3 = 3$, etc. The second part of the machinery consists of algorithms, or constructive rules, for transforming the elementary facts in memory into new elementary facts, or what is probably more important, for transforming new stimulus presentations into one of these elementary facts stored in memory.

An immediate problem of psychological importance with respect to a given body of problems is how much should be stored in memory and how much should be carried by the algorithmic rule. It is seldom the case that for a given set of problems we want all the answers stored directly in memory—it is certainly contrary to the usual spirit in teaching mathematics, but it is also unusual to want to store in memory only a minimal set of facts. For illustrative purposes, let me describe in some detail a way of teaching arithmetic that would consist of storing in memory a small number of facts and transferring the larger part of the load to the algorithmic rules. I emphasize that the example chosen is not one that is meant to have direct pedagogical applications. This system for computing sums is clearly not the sort of system we would wish to teach.

Let us suppose that our set of problems is just the following 21:

$$\begin{array}{lll}
1+1=n & 1+n=2 & n+1=2 \\
2+1=n & 2+n=3 & n+1=3 \\
1+2=n & 1+n=3 & n+2=3 \\
3+1=n & 3+n=4 & n+1=4 \\
1+3=n & 1+n=4 & n+3=4 \\
2+2=n & 2+n=4 & n+2=4 \\
4+1=n & 4+n=5 & n+1=5
\end{array}$$

We put the following four facts in memory:

$$\begin{array}{c}
1+1=2 \\
2+1=3 \\
3+1=4 \\
4+1=5
\end{array}$$

We have the following four rules of operation:

1. Use the four facts in memory to replace equals by equals.
2. Replace a term of the form $a+(b+c)$ by $(a+b)+c$, or vice versa.
3. Replace a term of the form $a+b$ by $b+a$.
4. Cancel an equation of the form $a+n=a+c$ to get $n=c$.

These four rules are then used to transform a problem, step by step, until we reach an expression of the form $n=c$. Thus,

$2+2=n$	Problem
$2+(1+1)=n$	by (1)
$(2+1)+1=n$	by (2)
$3+1=n$	by (1)
$4=n$	by (1)
$3+n=5$	Problem

or similarly, $3 + n = 4 + 1$ by (1)

$$\begin{aligned} 3 + n &= (3 + 1) + 1 && \text{by (1)} \\ 3 + n &= 3 + (1 + 1) && \text{by (2)} \\ 3 + n &= 3 + 2 && \text{by (1)} \\ n &= 2 && \text{by (4)} \end{aligned}$$

There are several immediate criticisms to be made of this setup, as I have described it. First, I have not been really explicit about parentheses in connection with rule 1. And I have not really made clear the role of the associative law, i.e., rule 2. More importantly, I have not written down a genuine algorithm for the set of problems. The four rules are four rules of proof, not an algorithm for solving any one of the 30 problems.

To convert the four rules into an algorithm, it is necessary to specify an order in which they are to be applied, and this order, to be efficient, should vary with the particular problem. Not only is it necessary to specify an order, but it is also necessary to show that the algorithm can be given to a machine and automatically used to solve any of the 30 problems.

To convert the present four rules into a genuine algorithm is somewhat tedious. Let me describe another, simpler system that may be used to solve the same 21 problems.

We put in memory the following five definitions:

1 = /
2 = //
3 = ///
4 = ////
5 = /////

Our algorithm is then the following:

(1) Replace all Arabic numerals by their stroke definitions and delete all plus symbols.

(2) If there are strokes on both sides of the equal sign, cancel one-by-one starting from the left of each side until there remain no strokes on one side. Ignore n in canceling.

(3) On the one side still having strokes, replace the strokes by an Arabic numeral, using the definitions in memory.

The solution in the form $n = c$ or $c = n$ will result.

Let us apply this algorithm to the two problems previously considered. First problem:

$$\begin{aligned} 2 + 2 &= n && \text{Problem} \\ //\ \ // &= n && \text{by (1)} \\ 4 &= n && \text{by (3)} \end{aligned}$$

In this case no canceling is required.

Second problem:

$3 + n = 5$	Problem
/// $n =$ /////	by (1)
// $n =$ ////	by (2)
/ $n =$ ///	by (2)
$n =$ //	by (2)
$n = 2$	by (3)

It should be clear from these examples how the algorithm may be applied to solve the other 19 problems in the original set, and moreover, how simply by adding new definitions in memory we may, without changing the algorithm, move on to similar problems involving larger numbers.

From a logical standpoint this algorithm is perhaps as simple as any to be found—here I shall not try to justify this statement by attempting a definition of logical simplicity. As far as I know, however, this algorithm has not been used in any first-grade arithmetic program.

Consideration of its possible use by children takes us out of the domain of elementary mathematics—the theory of algorithms for simple mathematical systems—into the domain of behavioral psychology. Once we enter this domain there are so many things to be said, I hardly know where to begin. Let me try to state some of the problems.

1. It seems highly unlikely that any children, without training, actually use the algorithms just described. The perplexing question is, what algorithms do they in fact use? At the level at which this problem is often discussed, the obvious answer is that they use the algorithms taught in the classroom and presented in their textbooks. But even casual inspection of the curriculum shows the inadequacy of this response, for algorithms for the 21 problems listed above (or with the numerical variable *n* replaced by a blank or box) are not explicitly taught, although some partial hints in terms of counting may be given. A typical curriculum instruction to teachers is to let the children find the answer "intuitively" by working with the numbers. Parenthetically, the use of the word "intuition" in its nominal, adjectival, or adverbial form by a curriculum builder, reformer, planner, or evaluator should be a signal to the behavioral psychologist that unexplained and ill-understood learning behavior is about to be mentioned and, unfortunately, often described as if it were understood.

So the problem remains, How do children in the fourth, fifth, or sixth month of the first grade solve problems like those in our set of 21?

2. A proposal often heard is that children solve such problems by simple rote learning. This is a possible response when any single

set of 20 or 30 simple problems is considered. It does not seem nearly as plausible when we look at the larger set of problems from which our 21 have been drawn. There are 55 ordered pairs of numbers summing to 9 or less ($0 + 0 = 0$, $0 + 1 = 1$, $1 + 0 = 1$, etc.). There are, then, 165 problems of the same type as our 21 ($n + 0 = 0$, $0 + n = 0$, $0 + 0 = n$, etc.). And the number of problems is increased further by adding triplets of the form $1 + 2 + n = 4$, $1 + n + 2 = 4$, etc. It is extremely doubtful that this large stock of problems is held in memory, available for direct access. The child solves them by applying some sort of algorithm. Some of the possibilities are the following.

(a) The child counts off the necessary number names, aloud or in silent speech. Thus, the solution to "$4 + 5 = n$" is obtained by counting off five number names after "four," namely "five, six, seven, eight, nine." The solution to "$4 + n = 9$" is obtained by counting off number names after "four" until "nine" is reached and then judging the cardinality of the set of number names counted off. Even without detailed analysis it is clear that the second kind of problem is harder than the first. The third kind of problem is still harder. The solution to "$n + 5 = 9$" is obtained by counting off enough number names such that five more take the child to "nine." It seems doubtful to me that the algorithm can be successfully applied in this form to the third kind of problem. Notice that no advantage has been taken of the commutativity of addition. Serious training on this problem would enable the child to reduce problems of the third kind to those of the second kind. The relatively greater difficulty that almost all first-grade children have with the third kind of problem, when the unknown is at the far left, indicates that, if the algorithm just described is used, it is not augmented by the commutative law.

For a great many different reasons it seems improbable that the algorithms actually used require very many closely knit steps to obtain an answer. The counting algorithm just described is realistic for problems of the form "$4 + 5 = n$" and not out of the question for problems of the form "$4 + n = 9$." For problems of the form "$n + 5 = 9$" the child may, without being explicitly conscious of it, make rough estimations of n and test the guess by counting. He remembers, say, that $5 + 5 = 10$, and "nine" is close to "ten," so he tries 3 or 4. Or, he may remember, that is, have in immediate storage, that $4 + 4 = 8$, and he uses this fact to guess 3, 4, or 5.

(b) In many ways the above discussion sells the counting algorithm short, because counting a set of number names like "five, six, seven, eight" aloud or in silent speech, seems difficult—the memory of "five" may have departed before "eight" is said. When the algorithm is externalized and applied in terms of physical objects (even the fingers) it seems much easier. I have seen something like the following used quite successfully in Ghana with harder problems than those we are now discussing.

The child has a counting set of pebbles on his desk. To solve the problem "4 + 5 = n" he first counts out 4 pebbles from his pile. He stops, and then counts out five more. This counting is done by simultaneously saying the number names "one, two, three, four" and pulling one pebble from the pile as he says each name. After counting out the set of four and then counting out the set of five, he then counts the separated set of nine pebbles and gets the answer. He solves the problem "4 + n = 9," by first counting out a set of nine pebbles and then taking 4 away, that is, by counting off a set of four from the set of nine. (It is to be emphasized that each of these counting operations is a highly physical thing.) After taking away the set of four, he then counts the remaining set of five to obtain the answer. Notice that the act of taking away four from the set of nine pebbles can be clearly and succinctly taught even though the subtraction symbol has not been introduced. As already remarked, lots of people have observed that for American children the "n + 5 = 9" sort of problem is harder than the "4 + n = 9" sort. For the counting algorithms just described they would seem to be on an equal footing. I think, but do not have real evidence at hand, that the Ghanaian children have the same sort of relative difficulty. The explanation is most likely to be found in the decoding required to pass from the written problem to the physical execution of the algorithm. The detailed analysis of how the stimulus arrangement expressing the problem sets off the algorithm will not be discussed here, but I may say in passing that this kind of example provides an excellent opportunity to analyze the behavioral semantics of the simplest sort of language. Briefly put, I interpret a problem format like "4 + n = 9" as a command in the imperative mood. The symbol "9" standing by itself to the right of the equal sign means for the pebble model "Count out a set of nine pebbles." The symbol "4" means "Count out a set of four pebbles from the set of nine." And, roughly speaking, the remaining phrase "+ n" means "Count the remaining set of pebbles and record the answer." For this kind of semantic the classical notion of truth is replaced by that of a response, or class of responses, satisfying a command. What I have sketched here in the roughest sort of way can be made precise by using with only slight modification the standard methods and concepts of formal semantics.

From the standpoint of the usual way of characterizing algorithms, the pebble-counting algorithm is unusual, for the operations of the algorithm are performed on the pebbles and not on the number symbols themselves. In this case the number symbols have meaning and this meaning is used to give instructions for performing the algorithm. It would seem that it is this sort of algorithm that many people now advocate in arithmetic in order to avoid the pupils' development of great facility with algorithms defined wholly in terms of the number symbols, since these may be learned without any "understanding of numbers."

(3) It is familiar talk to characterize the part of mathematics that may be reduced to algorithms as trivial. The classification of mathematical systems or theories as having or not having an algorithmic solution has been an important area of research in mathematical logic. What is not adequately recognized is that no adequate account of mathematical thinking can be given in terms of non-algorithmic concepts like that of "mathematical proof." Any adequate psychological account of mathematical thinking must surely be aimed mainly at finding the higher-order algorithms the student uses in finding a proof. What I had to say earlier about the study of association processes in the context of discovering proofs is directed to this point.

Mathematicians may not like the claim that the "creative act" of discovering proofs is itself an algorithmic matter. The only alternative seems to be a retreat into the mystical land of intuition.

APPENDIX B

NOTES ON THE PLENARY SESSIONS

DISCUSSION OF BRUNER'S "THEOREMS"

A Theory of Instruction

The discussion of Bruner's "Theorems for a Theory of Instruction" began at the beginning: Why do we need a theory of instruction? Can't learning theory handle the problem of instruction? There was sharp disagreement on this, but most participants agreed that, whether it can or cannot, it is not now doing so. Bruner suggested that instruction has two principal objectives: that the child learn a rule and that he achieve maximum transfer, that is, that he be able to apply this rule over a wide range of apparently disparate circumstances. A theory of instruction, then, aims to establish arrangements for optimizing encounters with the environment so as to achieve these objectives.

Learning theory has not addressed itself to these questions. The orthodox experiment has attempted to control out of existence "noisy" variables, such as attention, motivation, and structure, which are at the heart of a theory of instruction. Hawkins asked for more emphasis on ethological studies: Psychologists should more often depart from the rarefied air of the laboratory and take a look at the child and his teacher in their wild state. Whether or not the concepts of instruction theory must be congruent with those of learning theory, all agreed that the addition of new variables acquired in this way could not help but enrich the theory of learning. Henle suggested that learning theory has taught us little about meaningful learning; the rules for meaningful learning may be different from the rules for nonsense learning, and it is with the former that a theory of instruction is concerned.

Bruner speaks of "optimizing" encounters, but what is meant by optimal? Are we looking for the best way to teach children or merely for a better way? Is the proper strategy for research a kind of crude pragmatism—a "tinkering"—or does it involve a search for the kind of optimum found in calculus? Davis chided psychologists for their desire for perfection: Scientists know science is wrong, he said, but psychologists want psychology to be right. But Berlyne warned that we must not become enthralled by tinkering, that our ultimate goal must be, as it has always been, to find functional relationships. In any case, "optimum" must always be defined with reference to a goal. There is no "best" way to teach, independent of what is being taught.

Hawkins respectfully submitted that there are nonpsychological factors to be considered in designing a curriculum: The power of Euclidean geometry, for instance, depends upon the characteristics of space. Do we need separate theories of instruction for fourth-grade arithmetic and third-grade reading? This notion rather frightened the psychologists, but most agreed that there may be something different about the learning of different disciplines. Levin and Hawkins said that, even if this is so, the conference should concentrate on general parameters, on transdisciplinary principles which could be concretely applied in different disciplines. Bruner suggested, for example, that all disciplines demand simplification of expression, that the teaching of any discipline requires the choice of a critical unit. At the same time, no respectable curriculum could be designed except by people with a good grasp of the content area. This, according to some, is another difference between instruction theory and learning theory: the former must concern itself with what is being taught, while the latter does not.

In addition, a theory of instruction is concerned with the learner. A theory of instruction involves not only a theory of learning but a theory of development. Progressive mastery of a discipline depends upon the learner's repertoire of abilities at each stage. Finally, a theory of instruction deals with the instructor. Davis entered a plea for an anthropological study of what goes on in the classroom: What are the decision-making processes of the instructor? For example, what does she do when the child bungles a question? Does she smack him, pass on silently to the next pupil, hug him, give him a withering glance? Does she allow him to fail or not? Someone remarked that even if we could know what the teacher is doing, we do not know what the effect on the child will be. Brown made a recurrent plea for research to illuminate what he sees as a crucial variable for instruction: mutual comprehension between teacher and student.

Long-Term Predispositions to Learning

What is an "optimal" degree of exploration? Is it a case of the more exploration the better? No one thought so. Berlyne pointed out that a classroom of psychotics might be brimming with curiosity. Always, the gains from exploration must be weighed against the costs. "Optimal," here as everywhere, must be defined in terms of the goals of instruction. Do you want the rat to "understand" the maze? Then give him room to meander. Do you want him to speed pell-mell to his goal? Then close off the byways. Crutchfield suggested that, as instructional theorists, we want our rats to solve later maze problems more efficiently as a result of their experience with early ones. Levin thought that there was a time to explore and a time to store. Restle said that we do not want kids exploring "all over the place." Sometimes, he said, we want them to learn "the old way" of doing algebra. Bruner quoted Boring's remark that students must learn when to go into the laboratory and when to go into the library.

Garwin objected to Bruner's notion that risk must be minimized. Risk can be alluring as well as frightening to children. Perhaps, as Berlyne suggested, risk should be calculated rather than minimized. It depends, Kagan said, on the child. If he's afraid he may fail, then failure may be crippling; if he thinks he will succeed, he can tolerate failure. Bruner emphasized that the informativeness of error must be maximized. If the child is made to feel that *he*, rather than his idea, is wrong, he may show compensatory reactions: The teacher is no good, school is no good, I am no scholar. We do not know how or how much these reactions may shape his later learning strategies.

The difficulties faced by the teacher are often not strictly "cognitive" deficiencies in the pupils, Davis pointed out, but attitudes of hostility or apathy, toward the teacher or the material he is resenting: The child hates math or doesn't give it any thought. The school activity must have some value for the child. Donaldson mentioned a study showing that many first-graders have no idea what reading is for. Why, then, should they want to learn to read? Perhaps, Pat Sears said, they could be made to see the value of a skill in the course of learning it. If they do not understand the value of language, have them make up codes for communicating with each other. Give them maps by which they can locate a hidden treasure. Bruner cautioned that there is danger in offering practical extrinsic rewards rather than rewards intrinsic to the performance of the skill. Perhaps, he said, the good curriculum will create its own demand.

What skills do we want the child to have? What skills does he have, at a particular age, in a particular milieu? How can he acquire the necessary skills? Bruner suggested that there may be skills necessary to the performance of a number of disciplines—among them, the ability to simplify, to recognize invariance across transformations, to segment, to code, to pay attention.

What kinds of experiences lead to the development of such skills? Whatever they are, they do not appear to be present in the environment of the lower-class child, who so often runs into trouble in the middle-class American school. What goes on in the lower class? The assembled bourgeois admitted that they know very little about it. Some seemed to picture lower-class life as one of monotonic impoverishment, others as one of kaleidoscopic color and warmth. All seemed to agree, though, that social class is not in itself a meaningful variable, that it tends to blur the real variables. We need to specify the kinds of experiences assumed to be antecedent to the kinds of skills we are interested in. Bruner added that experience implies not mere exposure, but a contingent relationship, not just what objects and people are there in the child's environment, but what he does to them and how they answer him.

There is evidence that deprivation casts its shadow early on the cognitive processes. By age 5, Kagan reported, the IQ of many slum children is already "depressed." He hypothesized that the earlier the enrichment, the greater the gain. Is depression irreversible? Pat Sears thought "irreversible" was used too casually: Perhaps the degree of reversibility is at least in part a function of the teacher's patience and imagination.

Specifically, what are the cognitive deficiencies of the culturally deprived child? Davis reported that these children are at a loss when asked to describe something. They simply don't know how to describe. Brown said that lower-class children show less variety of grammatical construction than middle-class children. He mentioned the range of auditors specific to each class. Lower-class children may understand each other, and they may understand middle-class children as well as middle-class children understand them. But, unfortunately for lower-class children, it is more imperative to understand the middle class, because this is a middle-class culture. Brown asked for more research on the speech of the culturally deprived.

Children from different classes at different ages may differ in the coding practices they employ in their modes of economizing. We need descriptions of these various coding systems. Children's drawings offer a clue. They tell us, Suppes said, not how the child "sees" his world but how he codes it. We need to know the conditions and constraints upon the development of coding systems. Brown suggested that children can be given early practice in coding. Some of the Montessori techniques for scaling were mentioned. Henle asked what differences there might be between making discriminations among objects and making them on paper. The Russian educators' training of attention and segmentation were also noted. Should we change the child or change the school? Levin asked how slum schools could facilitate the transfer from lower-class life. Levin asked us to admit that, if we change the school, it is in order to change the child. If we exploit lower-class proclivities, we may do it in order to destroy them. The teacher may start by saying *dese* and *dose*, but she aims to teach the child proper English. Someone suggested that the best way to achieve transfer might be a return to the discipline of the old-fashioned school, birch rod and all. Everyone seemed to agree that the school should not offer a continuation of preschool experience but a means of building on it. Could this begin in nursery school? What goes on in a lower-class nursery school?

Structure

Is there a structure to all disciplines? Mussen was afraid that, although you could find structure in science and mathematics, you could not find it in the social sciences, in art, and other fields. Brown, too, wondered how one could teach structure in a field which had no established axioms. Bruner answered that he was tired of the historian's *mystique*. In any discipline, there is an attempt to get down to economical description; if there are no axioms in history, there are at least regularities. Davis, seconding this, pointed out that knowledge of the structure of Beethoven helps us to hear it better. Sometimes, regularities are hard to demonstrate. As Davis has found to his despair, the lab always disproves the lecture; the inclined plane does not do what it is supposed to do.

A central problem in instruction, Bruner said, is to get the child to see that there is a problem. In terms of the general problem-solver, how can we get the child to recognize the discrepancy between his present state and the desired state? This involves the modification of the child's currently held structure, and the best means of doing this may be to present him with a "counter-intuitive" case. Sometimes, regularity itself is against the child's implicit axioms. Berlyne proposed—and everyone agreed—that "counter-intuitive" was perhaps not the right word. What is going on is a special sort of conflict, which can be expressed in doubt, wonder, or surprise.

Baldwin asked, Does this really mean anything? Whenever the child's belief is wrong, we have a "counter-intuitive" situation. Berlyne and Davis were quick to disagree. The case presented must simultaneously make contact with the child's beliefs and contradict them. It must offer an occasion for conflict but the child must have some basis for resolving the conflict—not a ready resolution, but the beginnings of a resolution. Much that is taught nowadays, Berlyne said, has no relation whatsoever to the child's beliefs. By presenting the contradictory case and by not giving him the solution right away, we give the child pause. As Davis put it, the old way of teaching is to present the consistent case and say, "See! Doesn't that work just the way you thought it would?" This is a bore. Instead, show him that the old axioms will not work in the current situation; make him look for new ones that will. Also, Davis said, the contradictory case often forces the child to bring into contact previously compartmentalized contradictory views.

Why does this technique work? No one seemed to know for sure. When will it work? The scheduling of shocks and the child's tolerance for ambiguity are probably important considerations. Do some children throw out the axiom while others cling to it when shown an inconsistency? Why? Levin was worried: It is hard to think of challenges for the child's implicit axioms when we don't know what we are challenging. Bruner agreed, but found it an attack worth trying nonetheless.

Theory of Instruction

In his "Theorems," Bruner uses the term "instruction" rather than "teaching," because the intervention of another human being—a teacher—is not always necessary for learning. Instruction impiles an interaction between the tutee on the one hand and the tutor and/or the materials on the other. It does *not* imply that there must be an intention to teach or to learn.

4.3 of Bruner's Theorems states that, "Any problem that can be solved by presently available means can be solved by simpler steps than those now employed." Is this a useful statement? Suppes thought it might be meaningless, since we have no adequate formal criteria for simplicity and no behavioral criteria at all. Is the problem of simplicity a fruitful subject for research? Davis said that, in practice, this theorem is far from meaningless: The new mathematics curriculums can be called a "simplification" of the old in the sense that they eliminate much of the noise of the old. Bruner tried to explain what he meant by simplification. The instructor must make contact with the child's existing repertory of responses and build upon these. This may mean that the instructor starts with images and only later leads the child to print out the images in a notational form. (Davis and others, however, often succeed by supplying the notation first; there is no one representational sequence which is always right for every child on every problem.)

Davis remarked that what he and his colleagues need from psychologists is an instructional theory of some generality—not necessarily a full-scale theory of learning, but something beyond a compendium of nuts-and-bolts teaching techniques. They want to know what works in the instructional process and how and why it works.

For instance, is there anything common to the behavior and experience of effective teachers like Davis? Why do they get results? Levin asked, "Is there anything more than the personal artistry of a gifted teacher at work here? If so, this is what a theory of instruction must include. Pat Sears said there was evidence that seemingly simple behavior on the part of a teacher leads to better learning on the part of his students: listening to the child, eliciting his comments, offering him alternatives. Are there teaching techniques that can fairly easily be taught to an ordinary teacher? This needs more research.

Davis told of some of the possible reasons for his success. He is deeply committed to his field and to his particular curriculum: "I couldn't teach a course I hadn't helped to write." He believes in presenting material in small steps because large steps can confuse the child. In general, the younger the student, the smaller the steps. The child must be allowed to explore the consequences of a wrong answer, to see *why* it is wrong rather than simply to be told it is wrong. Teachers must not presuppose limits on the child's ability. Often, when a child is unable to answer a question, it is because the question is too simple—it seems to him silly or obvious. He may be able to answer a similar, more complicated question. There are at least three things to be considered: the complexity of the material, the size of the steps, and the order of the presentation of the steps.

Brown agreed with Davis on the importance of enthusiastic commitment in the teacher; the apathetic teacher is bound to reveal his apathy—he cannot manufacture convincing enthusiasm. It is also imperative, Brown said, to devise ways of guaranteeing feedback between teacher and student. Berlyne spoke of the importance of timing: The teacher's pause between asking a question and supplying an answer should lead the child to curiosity and search and finally to better learning.

Whatever may or may not be "right" about his own teaching, Davis said, it is clear that the usual teaching practices are "orders of magnitude wrong." Teachers in classrooms all over the country are wasting time making statements about matters which the child could discover for himself more quickly. Davis has never attempted any comparative measurement of his own success against that of the average teacher because "the needle would swing off the dial." With very little effort, instruction could be improved by 10, 100, or 1,000 times. Davis' plea is for experimentation in the field and for highly conditioned hypotheses—not "Is technique *A* better than technique *B*?" but "Is technique *A* better than technique *B* under conditions 1, 2 and 3?" Levin argued that his own choice would be to start with a simple hypothesis to see how much variance, if any, could be accounted for before going on to more elaborate hypotheses.

Most of the participants seemed to agree with Davis' complaint that there is no place for teachers to go where they can learn about the instructional process. Estes spoke up in defense of schools of education: "They don't teach anything because they don't have anything to teach," which is "better than being lazy or stupid." And Pat Sears thought a better defense could be made, though she agreed that education schools have no adequate theory of instruction, nor do they give enough attention to behavioral variables.

BALDWIN'S "INFORMATIONAL STRUCTURES"

Baldwin said that his paper (see appendix A) grew out of the belief that we need a taxonomy to handle the variety of cognitive structures which serve as mediators. The paper is an attempt to describe and classify these structures and to investigate how and when they change. Semantic connections, rather than associative congeries, like those of free association, are the important ones in cognition and important for education.

The rest of the discussion centered mainly upon ikonic representation. Asked to define the term, Bruner said that ikonic representation is a concrete visible embodiment of a general rule. What, Brown asked, is meant by "embodiment"? Does the image preserve the relationships within the thing—as in a melody—or must its elements match the elements of the thing—the notes? Perhaps, though not a simulacrum, the image must possess parts similar to parts of the object.

An image, Bruner said, is somewhat spatial and pictorial. Transitions are not picturable; images are static. Baldwin disagreed; some transitions are picturable. Perhaps, Bruner said, we have motion picture images as well as still picture images, or we flip the stills to produce a transition-image. Yet this does not really capture the nature of transition.

Suppes said that ikons must follow rules of correspondence; they must be isomorphic with distinctive features of the thing imaged. Ikons are always discriminative: The features matched depend upon the subject's set. Brown agreed and added that an ikon need have no similarity to its object; it must simply correspond to certain learned rules of representation.

Baldwin reiterated the distinction made in his paper between the ikonic ways of solution—"I don't know why I know it; I just know it"—and a (perhaps more analytical) going away and *thinking* about it. "Thinking" in this sense is formulated. In the ikonic mode, the criteria for belief are not specified.

Levin distinguished between ikonic metaphors for cognitive states (e.g., for theoretical systems, such as electricity) and ikonic representations of things. (The discussion up to this point was *not* aware of this distinction, a distinction which follows from the obvious, but here ignored, distinction between an image—a mental state—as a form of representation to oneself of a thing or a theory, and this self-representation as transcribed as an ikon or a symbolic message, intended to represent for others as well as self—*i.e.*, to communicate. It was this distinction which Bruner was driving at when he forcefully defined an ikon as a "concrete visible embodiment." Baldwin's term ikonic representation is apparently intended to refer indiscriminately to the purely mental images one evokes as a heuristic for the understanding of a fuzzy concept—"intuition" perhaps—and the concrete embodiment of these images in pictures or sentences describing them.) On the basis of this distinction, it becomes clear that ikonic representations may be no more than tricky attention-getters, whereas ikonic metaphors are crucial, and the time and condition of their presentation in a curriculum are important topics for consideration.

How can we tell what kinds of cognitive structures a person uses for self-representation of a thing? Baldwin emphasized that although you can ask people to make phenomenal distinctions, behavioral evidence is a better guide. Ikonic representation, he said, is "internal reliving." This seemed to imply that in ikonic representation, only minimal cognitive operations are performed on the stimulus when recalling it to oneself.

DISCUSSION OF GIBSON'S "DISCOVERY OF HIGHER ORDER UNITS IN INTELLECTUAL TASKS"

Why are we interested in "structure" and "units"? Because, Bruner said, we cannot know how best to present material to students without knowing something of the structure of the material. There are constraints upon the ways in which a structure can be decomposed without destroying the structure. Knowledge of the structure is a prerequisite for successful decomposition into units of presentation. Gibson was reluctant, at this stage, to define "units." Pressed by Restle, she said that she preferred the word "unit" to "element" because units are defined in terms of a superordinate structure.

Are units invented or discovered? Gibson thinks they are discovered: There are structural regularities to be found even in the apparent chaos of English spellings. She went so far as to say that units are objectively existent. Although the participants pounced upon this statement, they steered clear of prolonged philosophical debate by deciding that whether or not the unit was objectively existent was immaterial to a theory of instruction.

A highly vocal minority thought that units were formed through associative frequency, that the principle of transitional probability was all the "structure" there was. Gibson attacked this view. As evidence of its ultimate absurdity she cited Wallach's conclusion that learning to read is simply a matter of learning the sequential probabilities among letters.

Perhaps the probability approach has not been applied to the right units. The larger the unit, the better the approach seems to fit. Levin described some work in which the sequential probabilities between form classes were calculated from a large corpus of material. It was found that the form class that followed Form Class A, for example, was either completely determined, with P close to 1.00 or there were three or four alternatives with equal probabilities. So the pattern of form classes may be diagrammed $A \rightarrow B \rightarrow C \rightarrow \begin{matrix} A \\ B. \\ C \end{matrix}$ On going back to the data, it appeared that the places of indeterminacy correspond to the beginnings and ends of phrases, and were often marked by pauses in the speech.

Bruner suggested that acquisition of structure may not be a matter of learning probabilities *or* rules; perhaps the child learns probabilities which he later recodes into rules. This was as near a *rapprochement* as the group came. It is unlikely that these matters will be settled here.

Brown, who favors the structure hypothesis, told how one child went about acquiring language. The child developed the noun phrase *coat*: *a/the coat*: *my red coat*. At the same time, he was speaking simple sentences such as *take coat off*. Then suddenly in place of *coat* in this sentence, he began to say *take it off*. "It" is not a pronoun but a "pro-noun phrase." Thus the noun phrase is a higher order unit. Also, *my red coat* is usually separated from the rest of the sentence by pauses. The idea of functional equivalence or substitutability was introduced: units occur in functionally equivalent classes; that is to say, any unit can be replaced by another from the same functional class without affecting the structure.

Wasn't this child being reinforced for acquiring language, Berlyne asked? Yes, Brown answered, if "correction to the nearest meaningful utterance" is reinforcement, but this is an empty explanatory concept, since we are left with the problem of defining the nature of the reinforcement. A number of those present seemed to think that language was functionally autonomous, internally reinforcing to the child. Someone summoned up the picture of Weir's baby practicing his talking all alone in the crib. If reinforcement is internal, it is out of the teacher's control and of little use for either prediction or control. This matter, too, will not be settled here.

Gibson spoke of the distinction between "natural" and "coded" units. Natural units, she said, are related to perceptual organization. The distinction, Bruner suggested, is one of arbitrariness. Gibson was willing to accept this so long as it was agreed that coded units can have varying degrees of arbitrariness: Chinese characters, for instance, are less arbitrary than English words.

How are units combined? Do they form a hierarchy? A hierarchy implies a relation of some sort between levels. What are these relations? Beatie asked whether knowledge of the hierarchy within a subject will give you the best order for presenting it to the children? Suppes emphasized the importance of distinguishing between a *formal* (logical) hierarchy and one that is based on *behavioral evidence*. In a concept formation experiment, it is necessary to look at the behavioral data to decide whether the subject's concept in fact matches the concept designed by the experimenter. Do the behaviorally defined units match the formal ones? If not, which units of presentation will produce the better learning?

Supposing there is a formal and a behavioral hierarchy, and they agree, what sort of behavioral evidence will tell you the optimal order for presenting it? *Speed of acquisition?* Transferability? We need to know what kinds of things produce high negative transfer. There is evidence, for instance, that too small a step results in negative transfer. If you are trying to teach a hierarchically ordered skill do you start at the "bottom" and work up? At the top or in the middle? Gibson reported an experiment where the task was learning to pronounce (read) Arabic. The subjects were college undergraduates. Three groups of subjects were used. The first had preliminary training on the sounds corresponding to single Arabic graphemes. The second was trained by giving the sounds corresponding to 4 or 5 letter words. The third had no pretraining. The transfer was measured to the task of reading the same letters in new combinations. Both of the groups who had pretraining showed transfer, but it turned out that the group who had been trained on whole words fell into two subgroups. One had tried to learn whole words, and the other had spontaneously tried to learn the phonetic subordinate units. The latter subgroup accounted for *all* the transfer shown by the whole-word group.

Davis said that there are two ways of teaching a child a concept (like the concept of "variable" in mathematics). You can define the concept, and then consolidate by giving examples, by saying "a variable is . . . ," or you can begin with examples, letting the child build up or "discover" the concept for himself. There is only anecdotal evidence so far as to which of these is better. Davis was struck by the analogy between "variable" here and the pronoun in Brown's study. Perhaps the child acquired a skill in using pronouns which he puts to work later on the variable problem. Does the method of discovery work for all children? Some "skyrocketing" children will work during their spare time under the spur of discovery, at least in mathematics. This may provide a selection procedure for mathematicians. Perhaps the success of "discovery" depends upon the age and confidence of the child. Discovery, because it implies some freedom from guidance, increases the possibility of failure, which may be crippling to an underconfident child. Suppes emphasized, however, that we are talking about discovery within a discipline and not about the undirected discovery endured by Hunter School children in the 30's. The teacher can attempt to rig the environment so as to maximize the likelihood of discovery occurring. Donaldson remarked that there was much in the present discussion reminiscent of Whitehead's account of the three stages of Romance, Precision, and Generalization in education.

Crutchfield asked whether the technique of discovery is a generalized skill which should be taught. Should we think of transfer in terms of skill rather than content? *Are* there transferable skills? Henle said that we all know there are, but how to teach them? Suppes suggested that we need something between the over-general "education" textbook skills and the over-specific skills taught in the geometry textbook. We have no literature, he said, on how people actually arrive at their notions. All graduate students, for instance, have developed economical ways of using their heads; perhaps these should be legitimized and studied. Brown reiterated his concern with feedback. The teacher must know what ideas the student is presently entertaining, so that she can use techniques of correction when they count. Perhaps both child and teacher need techniques for making themselves mutually comprehensible.

CRUTCHFIELD'S RESEARCH ON SENSITIZATION

Crutchfield reported on a current project aimed at developing instructional materials designed to foster and facilitate basic cognitive skills in fifth- and sixth-grade children. He listed a number of working assumptions guiding his research, assumptions that, Levin remarked, represent an implicit theory of instruction that should be made explicit for the purposes of this conference.

1. There are general skills necessary across fields.
2. Such skills can be fostered and facilitated through techniques not restricted to a particular field.
3. Improved performance following practice with the experimental materials represents not the acquisition of new skills but sensitization to the importance and use of skills already present in the child's repertory and a redirection of his sets with respect to solving problems.
4. Schools do not now supply sufficient occasion for using such skills, nor do they give the child confidence in using them.

So far, Crutchfield has worked with programed instructional materials. The advantages of this approach are that:

1. It offers exceptional control of feedback;
2. It evades the problem of teacher training (Bruner remarked that this only postpones the evil day, and Crutchfield agreed, but felt that postponement was not to be sneezed at);
3. These materials can be readily adapted for wide use in varying educational milieux;
4. The approach offers exceptional opportunities for controlled experimentation, by varying the conditions the experimenter wishes to investigate.

The approach does not, at present, involve the use of machines, nor does it proceed by small steps down the Skinnerian path of simple reinforcement. It does involve carefully arranged written material, self-administered by the child, who writes in his own responses. Crutchfield entertained us by reading aloud some of his comic strips. The same cast of characters appears in all 13 lessons: Jim, Lila, and Mr. Search, who turns out to be their uncle. Crutchfield hopes that by the use of these characters he can maximize identification while minimizing the pressure on the child; for instance, the booklet is likely to ask, not what would *you* do, but what would Jim and Lila do? Whiting announced that if he were a child he would hate Jim and Lila, no matter how unprissy Crutchfield claimed them to be. Stevenson suggested that Jim and Lila may arouse more competition than identification; this could be tested. Henle commented that, since we know so little about identification anyway, the real question is simply whether or not the ploy works. Crutchfield has tried to minimize even cerebral competition because of his feeling that children are highly defensive about their ideas in the beginning. The saga of *Jim* and Lila is told in a sort of detective story form with the child actively participating in the solution of the mystery as he receives more and more information about it. Some of the problems involve constructing a puzzle, "How to make Mummy (Egyptian) go away?" Some are of the black box variety, where the child must figure out what is in the box. All of them, we thought, sounded pretty thrilling.

Levin worried that the detective story format might cause children to tear pell-mell through the booklet in order to find out how it came out. Perhaps, Crutchfield said, the children could be slowed or stopped by various ruses, such as presenting them with sub-goals. Children are encouraged to ask questions. Although it is not possible to provide them with individually tailored replies, the experimenters tried to anticipate questions. The children can look back over the evidence obtained so far, but they cannot look forward. Some of the principles of good thinking are explicitly recommended in the booklet; all are embedded in the stories.

Among the themes are:

1. the need to identify and define the problem appropriately;
2. the importance of asking questions and of taking time for reflection rather than leaping to conclusions;
3. looking closely at details, looking for discrepancies;
4. the need to generate many ideas;
5. the need to look everywhere for clues. (Often *Jim* and Lila are stymied; they pause, see something, get an idea);
6. not being afraid to come up with silly ideas.

Crutchfield has tried to discover the effects of the instructional materials on performance in problem-solving and Torrance-type creativity tests, and on attitudes toward cognitive endeavor. Two groups were tested on these tasks. One group then did the 13 lessons. The control group worked on lessons of a different kind, involving reflection and question-asking about a classic comic; the themes embedded in the treatment materials were not in their lessons. The attempt was to control for arousal of interest and involvement and for writing out one's own responses. Then the groups were retested on creativity, attitudes, and problem-solving.

Several types of problems were designed. Crutchfield mentioned the absence of good problems for use in programming. Some were "convergent," such as the modified Duncker X-ray problem. Some were divergent: for example, a child is being pursued by a vicious gang; he dashes into an elevator, alights on the fourth floor and runs up the stairs to the top of the building. Why did he not ride all the way up in the elevator? Some were somewhere between these two: for example, a detective, asked to investigate an old black house, spends the night in the house of its owner. When he goes to bed—very sleepy—he watches the sun set over the black house through his bedroom window. When he gets up in the morning, he looks out his bedroom window at the sunrise—no black house. What goes on?

In general, results on the problem-solving post-test show considerably more "elegant" solutions for the treatment group than for the controls. The word "elegant" was questioned, and Crutchfield agreed that "inclusive" was perhaps a better term. (The solutions are those which do not ignore data.) These results may be slightly contaminated by the presence of similar cases in the instructional materials.

Opinions of Crutchfield's results sounded a little like "Goldilocks and the Three Bears." Mussen thought they were much too good; Levin thought they were not good enough, and Suppes thought they were just right. All were impressed: "It should happen to us."

What is it that children learn from the instructional materials. Perhaps, Restle said, you are just convincing the child that the hints are part of the problem. Stevenson said that fifth and sixth graders operate on the hypothesis that they are being tricked; perhaps the instruction overcomes this and shows the child that improbable solutions can work well. Crutchfield agreed that all this was probably involved, but added that, although there were no wrong clues, there were irrelevant ones; the children had to do some sorting for relevance. On the other hand, as Davis suggested, Crutchfield may be sensitizing the children to noise, to clues which are not obviously relevant when they appear (particularly metaphorical clues).

Bruner asked Stevenson why children think they are being tricked. Is it that information as presented in school seems so arbitrary? Stevenson said that children at this age cannot accept a simple solution; they always suspect a gimmick. Perhaps, Bruner said, if children overcome their gimmick-orientation in Crutchfield's training, they are learning that information need not be arbitrary. Perhaps, he added, they are acquiring some faith that problems are soluble. Berlyne felt that at some point limits would have to be set: an infinite faith in solubility might lead to interminable wrestling with the actually insoluble.

Most of the participants felt that further analysis of the Crutchfield data would help us to know what the children learned. Even if the child does not arrive at a correct solution, how many relevant hypotheses does he produce? How soon? How soon do the different groups arrive at solutions? What is going on with the subjects who do *not* benefit from treatment? The group suggested that Crutchfield look for interactions with gender, IQ, and social class. Crutchfield mentioned some other enlightening bits of data. In one case, all of the children in both groups who had failed to solve the problem *had* assimilated the vital information. When asked to theorize on the basis of this information, however, the treatment children made less primitive interpretations than the controls—interpretations which revealed that they were on the threshold of discovery. In another case, 90 percent of the treatment group arrived at the correct solution before receiving *any* clues.

In the tests of creativity differences were sometimes minimal and sometimes fairly large, always favoring the treatment group. To test for change in attitude, subjects were asked to agree or disagree with restatements of themes embedded in the instructional materials; there seems to be a significant shift in attitude. A projective device asked the subject to rate Sam and Albert on various traits. Sam is a good guy. Albert is a bad guy, but bright. Albert's cognitive abilities were appreciated more following the treatment; before, his social undesirability seemed to mask his cognitive acumen. These results should be viewed with caution: Crutchfield is not happy about Sam and Albert.

A third attitude test looked for changes in the self-image of the subject toward interest in performing more creative and difficult tasks in problem solving; no such change was found.

Bruner was not surprised that Crutchfield got such large effects using similar pre-treatment and post-treatment tests. Poor Crutchfield, Restle said, is in the dilemma of all experimentalists: if his criterion tasks are too similar, we can denounce his results as trivial; if they are too disparate, we call it bad procedure. But all agreed with Bruner that the central question was one of the generality of transfer that can be achieved from this sort of training.

How can we test for transfer? Whiting and Bruner suggested a comparison of school achievement scores before and after treatment and between groups. The difficulty here is that there is so little problem-solving in most current curriculums. And as Henle said, what there is is so fragmented that the child is on a kind of assembly line; he cannot ever see the product of his thinking. Can we expect transfer to a dull classroom? Bruner cited the case of students trained in PSSC who are bored with college physics and drop it because it is so badly presented. Restle even suggested that Crutchfield's training might spoil the child for his school. Will he be less able to wrestle with teachers and textbooks that are apparently trying to hide information from him? Donaldson thought that we had to know more about what goes on in the classroom before we could think about the problem of transfer intelligently. What is the situation we are transferring to? Morrisett suggested that we might test for transfer by the speed of learning—the savings—in a new area.

Levin contrasted the old type of transfer research—if you learn to be neat in writing are you neater in arithmetic?—with Crutchfield's skill-activation. Where content is incidential, it should be easier to achieve transfer of the Crutchfield learning.

How much transfer can we expect? It will not be infinite, Suppes said, nor is it appropriate to transfer these skills into all areas. Everyone agreed, but disagreed on which areas were most appropriate. Pat Sears, for instance, worried about transfer to real-life situations, where clues are infinite rather than selected, as in Crutchfield's material. Donaldson and Bruner pointed out that we need to know something about the duration as well as the range of transfer: How long do these skills stay alive, with and without activation? And does one skill interfere with another? Do we achieve brilliant analysis at the expense of proliferation of ideas?

The question of appropriateness of transfer came up again in a recurrent theme of this conference. How general are these skills? Whiting had something to say. Although he agreed with Bruner that we are faced with the necessity for simultaneous formulation of objectives and strategies in education, he argued that strategies cannot be considered independently of goals. If you are teaching values, critical thinking is the last skill you want to encourage. For instance, if you are teaching Greek for the purpose of producing an in-group of linguistic snobs, proliferation of ideas is not really relevant. This precipitated a table-pounding discussion generating a good deal more heat than light. "The teaching of values is latent in the schools." "Yes, but should it be latent in this conference?" "We don't want to train rigid people for a changing world." "We don't want to raise kids with no anchorage." "You're going to train a nation of skeptics, and then what happens to the values of this culture?" "The schools are no good at transmitting values anyway." Suppes finally declared, as he would again, "We won't get anywhere with our answers to these questions. Our answers won't make any difference." It was time to adjourn.

DAVIS' MATHEMATICS FILMS

Beyond basic arithmetic techniques and mathematical facts, Bob Davis' Madison Project is concerned with making the child familiar with fundamental mathematical concepts such as variable, function, and open sentence. And beyond these there are underlying values to be transmitted: a belief that math is discoverable and that the child himself can make the discovery, a belief that math is open-ended and ever-changing, a belief in self-criticism and analysis, a commitment to abstract rational analysis, and confidence in the power of educated intuition.

Discussion became more general when the question of means arose. Davis emphasized the need for a task-oriented rather than a time-oriented curriculum. Bruner pointed out that the teacher must impose enough constraints on the learning situation to lead the children into the material carefully—but that she must stay out of the way of the mathematics. Pat Sears hoped that children would not be overloaded with more than they could handle and objected to a statement that novelty alone might be the biggest single factor in engaging the attention of the child. No one, however, saw fit to wonder how the slow learner was made to feel at home in the quick-moving, noisy atmosphere shown in the films.

A more specific form of the old question of individual differences now engendered heated discussion, centering around the difficult ages of 7th and 8th graders. Bob Davis began with a remark about the junior high child's lack of interest in abstract mathematics—only engineering could interest them. The new social structure in the junior high coupled with the necessity of "finding themselves" precluded giving their interest to abstract problems. Whiting suggested separation of the sexes (the old business of emphasizing rather than minimizing differences), but Pat Sears thought a better idea would be to give them material from literature and social science which should interest them more. This led to general discussion on whether or not there are critical ages for certain subjects and whether it might be better not to teach everything all the time, even though it is theoretically possible to find a way of meaningfully teaching it to any child at any age. The value of concentration versus the disadvantages of interference was argued, with "we need more research" the only generally agreed upon statement, as usual. Phil Morrison caught the mood, if not the consensus, perfectly with his statement, "Why send them to school at all? No one offered any data on K-8 school systems which do not have separate junior high schools.

It was suggested by Bob Davis, and seconded by all concerned, that psychologists might prove of assistance in investigating the following questions:

1. What are the effects of this curriculum?
2. What are the implicit assumptions of the writers of this curriculum?
3. Will the early teaching of real math lead to adolescent rejection of it because it is "what I did as a kid"?
4. What are the emotional and curricular predispositions of children of different ages?

This plenary report is intimately related to the discussion with A. Gleason and E. Gegle of the Second Generation Math Project.

DISCUSSION OF GENERAL SKILLS

Restle asked, "How do we know what skills are general?" Is vision a skill? There are differences, Bruner suggested, between capacities and skills; we look for techniques for turning the former into the latter. On what level are we speaking? Are we talking about "big operations like the search for similarities and differences, or about more specific ones like techniques of condensation? Berlyne suggested that we not limit ourselves to thinking skills, which are not always the most efficient strategies for solving problems: the dons in the Oxford common room might do better to consult an atlas than to debate the question of the size of the population of India. The population of India, perhaps, is not a problem but a fact. But perhaps we should not limit ourselves to problem-solving skills.

It seemed to be easier for the participants to list generalized skills than to define them. Their catalogue of cognitive skills included techniques for transfer, simplification, planning, identification and definition of the problem, recognition and abstraction of relevant data, use of analogy, and seeing the symmetry in a solution.

There are skills other than cognitive skills that make a difference, affective-attitudinal variables that affect academic performance. Perhaps the most important of these is a positive attitude towards problem-solving, which combines reasonable expectation of success with the absence of profound fear of failure. This is the cheeky kid who is willing to have a go at the problem. This sort of "skill," Morrison suggested, is more likely to be transcurricular than any other. The toughest problem he faces as a teacher, Morrison said, is to get the child started. The right answer to a problem in physics can be reached by a number of roads. The problem is to get the child started down one of them, even a wrong one from which he may get a view of the right one. Levin argued that impulsive commitment—diving in—may work better in physics than in other fields. Do we want the same degree of cheekiness in our English students? Another desirable attitude is a willingness to shift strategies when the first strategy fails to pay off. Here, as elsewhere, what is required is a delicate balance. Don't be afraid to push your idea, but don't be loath to drop it.

The discussion moved outside the child into the matter of what Bruner called "amplifiers," external devices for increasing cognitive power. The traditional psychology of thinking, he said, has implied that we are all resourceless savages, when in fact our culture provides us with a number of such devices. When Morrison wants to ignite his pupil, he gets him to make a diagram translating his words ("The wind is blowing from the east at 30 miles an hour") into a picture (an arrow). The diagram is useful because it is a noiseless version of the original statement, containing all the information and only the information relevant to the problem. Morrison argued that any recoding was of value, but Brown said that it was the stripping of the irrelevant that was crucial. Mussen agreed. At the moment of recoding the student must decide what is relevant in the given context. The restriction to the relevant can, however, involve a danger of rigidity. Sometimes, invention proceeds from the apparently irrelevant detail.

Brown asked about the recording device of note-taking. We need information on how to train good note-takers. Essentially, the problem here is to anticipate what you will need to retrieve at a later point in time. Morrison asked, How can anyone possibly divine this? Brown said the real difficulty is that there is no corrective feedback, no way of knowing how well the reconstruction on the basis of notes matches the original stimulus (except for the rough index of the examination grade).

Crutchfield summed up the discussion. Recoding has three functions: it eliminates surplus—irrelevant—meanings; it represents and consolidates motivational commitment to the task at hand; it allows the student to test his grasp on the problem. All of these, Mussen said, are only potential benefits; sometimes recoding is inappropriate. Bruner added that the new medium must allow the student new opportunities for manipulating the material.

A change in topic was heralded by Whiting's seemingly innocent remark that all children should acquire techniques of verification, and that the appropriateness of such techniques may vary for different disciplines. On what basis should you retain or reject your ideas? In mathematics, rules of coherence are most salient. In science we are more likely to use tests of correspondence to a physical reality. Value statements are tested by reference to an authority. The trouble began when Whiting asserted that social studies is and should be concerned with the transmission of values. (He distinguished social studies from social science, which does call for coherence and correspondence testing.) (Some of the controversy which followed may have arisen through failure to make the distinction between actual *statements*— which may contain particular clauses to which the rules of coherence and correspondence may be applied—and the immutable, often tacit, beliefs which prompt the statements.) Bob Sears argued that most value statements are based not on authority, but on extrapolation from errors in coherence and correspondence. Bruner asked us not to forget, midst the furor, that the question of authority is important. Most children don't know how to decide which authority is relevant.

Whiting added the controversial statement that in the humanities what is principally involved is appreciation. The reference is entirely personal; the only test of validity is the idiosyncratic emotional response of the student. Sears suggested that beyond this there is a kind of appeal to authority here, at least to the authority of consensus; there are some grounds for throwing out an utterly eccentric literary criticism. Bruner agreed. An interpretation of *Moby Dick* is not entirely idiosyncratic; any critic must cope with the fact of the whale. Also, some cogency is required. Whiting's reply to all this was that literary criticism does not involve appreciation anyway—it is depreciation. Suppes suggested, and Whiting agreed, that there is an aesthetic to physics. Morrisett said, "You can teach any field as an art or a humanity." Bruner suggested that, "Perhaps a plenary meeting is not the sharpest instrument to bring to bear on these problems." The participants, appreciative of this diplomatic stroke, returned to the problem of generalized skills.

Some large questions were asked, including the persistent one of transfer. Kagan asked, How can we design a curriculum for fourth-grade math which will make seventh-grade math less tortuous for Davis and his students? The problem of transfer, all agreed, is related to the problem of structuring of materials. Levin mentioned the importance of sequence. For instance, there seems to be a mid-point where writing helps reading; introduce writing earlier or later in the instructional sequence, and the effect on reading will be different. How much success should we build into the curriculum? Kagan thought the child should succeed as much as possible. But maybe the child needs some failure "antibodies" lest failure be disastrous when it inevitably arrives.

How important are individual differences for a theory of instruction? Stevenson said that a major function of this conference could be the bringing to bear of developmental knowledge on the instructional process. Most of the new curriculums, he said, leave the child entirely out of the equation. Suppes, however, said he has yet to be shown that individual differences need affect the arrangement of instructional stimuli. But if there is no evidence, Whiting said, perhaps it is because no one has looked for any; it is a research question. Although not everyone agreed with Whiting's notion that the first step should be to find out whether differences are genetic and immutable or culturally determined and mutable, all seemed to agree when he said, "Let's stop stating our beliefs and do some research."

Assuming differences like those of gender or cognitive style are relevant to instructional arrangements, what do we do about them? One approach is to let them stand and tailor the curriculum to fit. Kagan said that math is a male-typed activity by the first grade; by the fourth and fifth grade, boys are performing significantly better than girls. We could overcome this by using different materials for girls—counting piepans instead of baseballs. Pat Sears objected to Kagan's leap from the evidence of sex-typing to curricular segregation. At this point, she said, we should be asking questions rather than making panaceas. She seconded her husband's suggestion that we look into the causes of these differences. Are they due to role-training and hence are they retrainable? Whiting made one of his "citizen-type statements" to the effect that we should not only let the differences stand but maximize them. "You want to train women to think like men instead of bring up children." At the very least, a number of participants thought, we can provide for alternatives in our curriculums that might reduce the penalties for unfashionable styles.

Another approach is to attempt to overcome individual differences. Here, differences seemed to be defined in terms of deficiencies. Train the highly symbolic child in image-making; give the imager special work with manipulation of symbols. The purpose of this is not to produce uniformity of style, Bruner said, but to activate each child's entire repertory of representational skills. (Pat Sears remarked that the existence of such a repertory is open to research.) In the case of differences in male and female performance, Henle asked, is it a matter of differential motivation? If so, how about trying to teach the girls a positive attitude towards problem-solving? Crutchfield proposed a research plan which would simultaneously allow for instructional alternatives and for investigation of the effect of the alternatives on learning; set up a multiplicity of tracks, and check at nodal points for differential effects. Suppes put forth a threefold proposal for:

1. A cognitive-style analysis of curriculums, especially the new curriculums. Kagan was not sure that the constructs of cognitive style were well enough developed for translation into curricular terms.
2. A study of the discrepancy between the cognitive style embodied in a curriculum and in the teacher who is teaching the curriculum.
3. An analysis of curriculums from a learning-theory standpoint, that is, an examination of the notions about learning implicit in the curriculum (and rarely recognized by its creator).

Suppes mentioned step-size as an example of the sort of dimension he had in mind. Bruner endorsed the idea of curriculum criticism. There is a world of difference, he said, between the PSSC assumptions (e.g., conflict is good) and those of the *Time*-capsule devices put out by the Luce publications.

MATHEMATICS:
DISCUSSION WITH A. GLEASON AND E. BEGLE
SECOND GENERATION MATH PROJECT

Second Generation Math Project (SGMP) is concerned with transmitting two things to children: certain mathematical skills and the "ability to think mathematically." In attempting to develop computational skills, however, a pragmatic criterion must be employed: Drilling on long lists of additions and multiplications must not take the place of basic understanding of mathematical operations and concepts. The evidence gathered so far from the School Mathematics Study Group indicates that computational ability will follow as an epiphenomenon from the understanding of basic concepts—students with this training who spend much less time on drill do no worse on standardized tests of computational ability than children who follow the usual curriculum. Beyond arithmetic skills, the ability to estimate is important. Other specific subject matter goals include a thorough grounding in calculus, linear algebra, probability and statistics, and geometry, the latter as a training in math discovery. Teaching partial instead of linear ordering might help to prevent, for example, the fuzzy thinking prevalent in discussions of "left" and "right" in politics. Finally, it is important to give training in the proper ways of applying mathematics—building mathematical models for problems in real life and moving back and forth between the model and reality.

"Thinking mathematically" is basically the ability to think combinatorially, whether or not this is accompanied by specifically mathematical content. Thus, as Levin pointed out, it is possible to teach mathematical thinking without teaching mathematics. In addition, the child must learn not to be frightened of complicated numerical problems. He must learn to simplify these problems before performing tedious calculations. And he must learn to recognize contradictions and give good reasons for what he does.

This, as Bruner pointed out, brings up the question of what can be expected of a child at a given age. Though a child can quite readily recognize perceptual contradictions at the age of 4, can we conclude that conceptual contradictions are also accessible to him? Moreover, semantic contradictions are not recognized at this age. Goodnow and Donaldson felt that Piaget-type experiments placed limits on what you could teach, but the mathematicians agreed that difficulties of this type would most often be trivially solvable by more detailed and patient training. Some ikonic representation can always be found which makes the material accessible to the child. But we cannot always be sure that children learn the lessons from our models which we want them to learn.

Ultimately, the success or failure of curriculum revisions in mathematics will depend on whether a connected, interesting set of problems can be created. So far many children have derived motivation from the abstract structure of mathematics itself, but to be most efficient we must introduce mathematics in a matrix of scientific reality. Unfortunately, science teaching in grades 3–10 is at such a low level that there are no examples available to the mathematician writing problems. Presentation of downstream-upstream problems without the prerequisite understanding of physics turns into sheer rote learning, an intellectual fraud. And children don't seem to be interested in the supermarket either.

A second problem of means is that of units of instruction. Here again the mathematicians agreed that old-fashioned, time oriented, "we're done with fractions, now you can forget them" units must be discarded in favor of an ill-defined intuitive approach which scatters various pieces of mathematics throughout the grades. The psychologists raised the specter of interference phenomena, but too little is known to make any definite predictions. Gleason suggested that the most natural units were those which ended in some sort of intellectual triumph for the student (such as mastery of the two-body problem with the techniques of elementary calculus). All agreed that teacher cooperation and training were crucial. Perhaps teachers could be allowed some voice in the planning of curriculums, thus helping create enthusiasm among them for what they are teaching. Mention was made of Buck's recommendations about training of mathematics teachers for different educational levels.

In the final half hour, the mathematicians attempted to indicate areas in which psychologists could help them in their task:

1. By creating tests which would give a true measure of the effectiveness of curriculums. The present standardized tests are wholly inadequate.
2. By creating a decent measure of transfer from one learning situation to another.
3. By providing detailed studies of curriculums analyzing in particular what assumptions about the learning process underlie them.
4. By providing a detailed ethological study of the classroom.
5. By showing how best to deal with individual differences—a problem at present left entirely to the individual teacher.
6. By an analysis of what the proper units of instruction should be.

7. By telling when it is best to present concrete material before abstract, and vice versa.
8. By a longitudinal study over a long period of time of changes in attitude toward mathematics.
9. By theoretical statements on what the problems are, how to recognize them, and how to design experiments to deal with them.

It is to be noted in the above discussion that precisely those questions which have recurred throughout the sessions of the learning project were raised by the mathematicians in their discussion.

Preliminary Reports of Work Groups

Group 1: Attitudinal and Affective Predispositions for Learning

Why is it that the correlation between a child's IQ and performance is so much higher in school than in the laboratory? Kagan suggests that school performance reflects not only capacity but feedback upon an attitude: The bright child knows he is bright, thinks he will succeed, and so he does succeed. Faced with a new task, in a new context, the child is less entangled in his self-image. This points up again the importance of getting the child to make a first successful step. Children get trapped into one track early in their schooling. Girls begin by avoiding math out of choice, but this very choice plunges them into an increasingly restricted—mathless—environment, where mathematical stimulation cannot occur. Pat Sears cited the Fels Institute data, which indicates that twice as many boys as girls show ascending IQ between the ages of six and ten, and that this ascendance is correlated with factors such as curiosity, independence, and need achievement. Boys, she thought, learn more from interaction with their environment because they are somehow freer in their interactions. The effect of this freedom—or restriction—is cumulative.

Groups, as well as individuals, can become caught in this way. There are strong peer-group influences on learning. Davis has noticed in giving demonstration classes in mathematics across the country that, if any child does well at the beginning, a sense of the solubility of problems shoots through the classroom; if the first children muff the question—make it seem difficult—they set off an equally contagious sense of insolubility. How can we achieve a class commitment to excellence? Are we, in segregating the gifted children, compounding the problem for the less gifted, by stealing the students who might make those successful first answers? Perhaps we should try to provide alternative routes for success. Bruner told of a Harvard freshman who, upon learning that he could not be top of the academic tree, "Ran for the niches." Brown said that Harvard was a less punishing atmosphere for students than MIT precisely because Harvard provides the niches, while MIT has only one criterion for success—grades. Sears has found the same distinction between the engineering and hard sciences on the one hand and the humanities and social sciences on the other at Stanford. Is there a curriculum-specific style—or value-system—at work here?

Rather than running for niches, children often simply withdraw. Afraid to express their ignorance, they cannot learn. Perhaps children can be trained to express ignorance. Brown wondered if schools could borrow role-playing techniques used in industry to thaw out communication between pupil and teacher. Let the child play a game with the teacher in which he expresses his ideas or his ignorance without being personally attached to them. Brown asked whether the communications freeze was made harder by the fact that the teacher must wield power through control of resources. Kagan thought that the age difference alone was sufficient to make the teacher appear powerful. By grade 5 or 6 though, Pat Sears thought that competence is probably the major cue to power. Perhaps teachers in the early grades should not be asked to deal with materials beyond their competence; curriculums could be designed which allowed them to express their general adult competences. Davis argued against this notion: It was the teacher who took mathematics away from associative laws and into the supermarket. The shift makes the teacher more comfortable, but it wrecks the math.

Group 2: Methods of Stimulus Control

Brown offered language as an example of a skill that we know is transcurricular and that we know is not usefully taught now. A useful curriculum could include practice in coding and decoding, exercises to show the difference between saying and thinking, and exercises to show tone of speech as a means of self-expression. The usual curriculum moves too quickly from rudimentary knowledge of reading and writing to the expressive essay. What should be stressed is precise communication.

Group 3: Internal Cognitive Skills

What do we know about attention? Most of the literature on attention concerns momentary distraction, but little is known about the determinant of sustaining attention over a structured activity. Perhaps we should look at the literature on persistence. When stuck with a problem, people often put it away for a while and do something else. Does interference theory tell us this is inefficient strategy? Probably, it tells us nothing. The interference data is concerned with retrieval rather than with productive thinking or artistic creation. Levin mentioned the case of Mark Twain who periodically ran dry on his novels; at this point it was his practice to put the novel away and turn to writing potboilers for a while, after which he would resume the novel. Interference theory, if relevant, might frown on the similarity of his intervening task. Actually, interference *did* occur: When Twain resumed the novel he misnamed his characters. Is interference *good* for creativity?

Baldwin mentioned how difficult it would be to interpret correlations found through factor analysis among different cognitive skills. Are the correlations a result of correspondences between skills built up within the child, or are they correlations within a school curriculum? For instance, Johnny goes to a good school where arithmetic and English are both well taught. Perhaps, in such a study, we should randomize the children's treatments. Henle asked to what degree teachers see different subject-matters as related. The general view seemed to be, not at all.

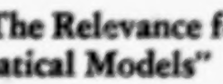
Discussion of Restle's, "The Relevance for Education of Mathematical Models"

There are two ways of making simple discrimination learning difficult: first, by making the difference in the values of the relevant cues just barely perceptible, and second, by adding a lot of noise in the form of irrelevant dimensions that are varied.

The problem discussed is the fact that starting with an easy discrimination and working towards a difficult one is a more efficient way of learning than simply working on the difficult problem the whole time. Lawrence showed in a brightness discrimination that when rats switched from an easy problem to a hard one, the savings more than compensated for the previous training on the easy problem.

The problem is that S–R theory would not predict this—it would say that the only difference between the two groups was performance and the rats had learned the same amount.

Restle suggests two related hypotheses to explain this data: The rate of learning in the easy condition is actually faster, because the relevant cue is more salient, and second, that the rate of learning depends upon the proportion of relevant cues.

North's experiment with rats  where the relevant cue was the direction of the lines on the path the rat had to cross and where the "easy" situation had the lines raised slightly from the floor points out clearly the "drawing attention" attributes of the easy situation.

The Elementary Science Study

David Hawkins

Hawkins began his description of the ESS plan with a plea for human ethology in "optimal classrooms": observation of the teacher-student interaction. He went on to describe the trial-and-error teaching method, in which short-term ad hoc experiments, with continual feedback from classroom observers, bring about an evolutionary improvement in technique. The objection to long-term experiments (executed by remote control) is the wooliness of the feedback. It is wise to have the experts in subject matter fields do the teaching themselves so that they can then learn something about students, about traditional teaching techniques, and about the various grade levels which will help in the planning of curriculums. The curriculum planner must know about learning, development, and subject matter.

Three basic kinds of learning experience were described: that which results from an effort to assimilate a discontinuous or disconcerting experience—the fitting together of reality and principles; that which results from a breakdown of old assumptions about the nature of reality; and that which is paced passively to outside reality, which consists of "summarizing and encompassing" new experiences as in learning about the life of the butterfly. The last of the three is a less analytic kind of learning.

The aims of the science program are very wide—attitudes and some content, in a "pre-disciplinary" sense. The program is based on the assumption that children want to experiment. It was noted that the larger the equipment, the better the results; that up to a certain level of abstraction, the younger children seem to proceed more rapidly and cheerfully in formulating explanations than the older children, perhaps because of an overlearning of the habit of verbalization in the older children. On the other hand, Hawkins said, there can be too many "things" and too little detached thinking with this technique.

Sears asked about transfer effects with these teaching techniques. Hawkins described the kind of change in self-concept which accompanies mastery of experimental problems, in turn affecting motivation for solving subsequent problems. He explained that transfer of particular problem-solving techniques, or ability to make use of analogical connections between bodies of subject matter, can only arise when the two subjects are being learned at the same time, or, if they are learned in sequence, after some portion (a sub-domain) of the chronologically later subject has been mastered. There was some controversy over this point; most of the group seemed to feel that all exploration of a new topic involved some transfer of general or specific skills from previous learning. Hawkins pointed out an obvious exception to this rule: the introduction of a totally unfamiliar phenomenon to a young child. The general ability to transfer develops with age and is manifested by shorter and shorter preliminary periods of exposure to the new topic before the appearance of transfer.

This discussion led Restle to remark that preliminary *play* with objects—amounting to free exploration—is necessary if later intellectual operations involving those objects are to be maximally efficient, as shown by work with chimpanzees. He pointed out that something very important, probably discoverable by observation, must be going on during such play. There were some remarks about the advantages and disadvantages of replacing time-consuming play with a more directed learning experience, using verbal instructions about equipment, and so forth. The relative value of the contrasting procedures is an empirical problem. Bruner said one might expect that curtailing all free play and exploration would be detrimental to the development of brash initiative. On this point, Hawkins described the distinction between eolithic behavior and behavior constrained by hypotheses. Both are useful for different purposes.

A discussion of the value of inventiveness, both in teachers and students (Hawkins: "All people are equally inventive") led Restle to ask whether Hawkins had a measure of the inventiveness of students after some teaching procedure; whether, for example, manipulations with the beam balance would reveal a change in inventiveness. Hawkins replied that such a measure would be too uni-dimensional to rank children successfully on a general trait like inventiveness, and Restle explained that he was interested not in individual ranking on a trait, but change in the mean level of inventiveness in a class as the result of learning, assuming "inventiveness" to be one of the goals of some given instructional procedure. This exchange opened up an argument lightly touched on earlier in the session, when Hawkins gave as an example of their only criterion test (aside from the reports of classroom observers) the teacher-to-teacher question, "How did it go?" adding that quick tests of short-term results were needed.

The argument that followed hovered incoherently around the following issues. In order to plan a curriculum, goals must be recognized and organized into a hierarchy. The program of instruction is then planned in a manner which, plausibly, will implement the goals. Evaluation can then be done on any level of generality of goals, from vague and long-range to specific and short-range, although the measurement of the achievement of the latter will usually be simpler. The question of how this can be done, and of how useful it is when short-term goals are constantly undergoing change, received energetic attention from the group. Eventually, consensus was reached on the desirability of having a "systematic ethologist." Then the question of what specific instruments to place in his hands was taken up. Do you measure the mastery of bicycle-riding by observing the pupil ride a bicycle, or by asking him to ride a motorcycle? The ensuing argument seemed to be based, in part, on a disagreement about the level of specificity of the goal being tested: Are we just interested in bicycle riding, or something more general, like the principles of two-wheeled vehicles? Where work with the balance beam is intended to achieve understanding of scientific method even more than possession of a specific skill, achievement with the balance beam alone would be an equivocal test of arrival at the ultimate goal, and a (related) novel task would be more appropriate.

Sears suggested that the systematic ethologist record separately: (1) a measure of the progress of the students, (2) the elements in the teacher-student interaction hypothetically responsible for the students' progress. The discussion of evaluation ended on a grim warning from Restle to Morison and Hawkins that, if the curriculum designer does not construct tests, the school principal will—"And you don't want that!"

Levin wanted to know whether it would be possible to teach psychology to ninth graders, and Hawkins described some ways in which it was already being done. Brown asked about encouraging verbalization by requiring students to keep in mind that they will have to report to an absent classmate on their observations. Hawkins agreed that this would be a good idea, and that it had not been done.

The discussion returned briefly at the end to the problem of evaluation, and the following points were made: Some tests should involve activity other than with pencil and paper; tests should be multidimensional in order to equate children who may have differing specific responses to a given instructional procedure—variance of this kind being something to encourage.

Problems of Instruction in Social Studies and Humanities

Elting Morison, professor of history at MIT, and members of the conference exchanged anecdotes in an informal session that was something of a relief after several days of what Hawkins called the "elegant austerities" of science and mathematics. Morison's narrative style is inimitable; this report will deal only with the dry bones of the discussion.

In mathematics and in hard science, Morison said, you can operate to a fairly high degree without intuition, but in the humanities and in the social sciences analysis is not enough. General propositions cannot take you very far toward discovering the essential consistencies in human relations, the things that hold situations together. Garwin objected that math *does* demand intuition. Perhaps, Restle said, the distinctive effect of humanistic learning is the ability to see new discriminations; there are new differences in the world, new structures visible which were not there before but, once there, cannot disappear. Bruner agreed: The difference between the "hard" and "soft" fields may be a difference between convergence and divergence. While knowledge in mathematics and the natural sciences leads to convergence upon a given discoverable structure, in the humanities and social sciences it leads to explosion outwards in diverse directions.

In these fields the student must be willing to make assertions which he cannot prove. There is in all men, Morison thought, a "fierce fascination" for rigid closure—a need to tie up the problem with a neat answer. Because of this, we tend to exclude from our curriculums and our minds problems which do not admit of unambiguous solution. How do we cope with this innate intolerance for ambiguity; how can we build into children what Henle has called a "zest for ambiguity"? Is this a medical or a pedagogical problem, Morrison asked? Can pedagogical arrangements help? The school should make available to the child the compensations Morison has found in his own life for the burdens of ambiguity: There is a kind of proud possession involved in taking a mass of data and making them fit together; one can organize according to one's own criteria, without interference from others. Is there something in the school situation that is antibiotic to the intuitive germ? Certainly art rarely thrives in the groves of acadème. Morison's daughter, who "read" *Rip Van Winkle* in school, may remember that it contains a pathetic fallacy, and that it builds to a climax on page thirty-seven. What she does not remember—and probably never learned—is what *Rip Van Winkle* is about. Morison read it at his mother's knee, and he remembers still just what it was about. Perhaps the secret is in the one-to-one relation of the child to his mother. Can the teacher develop intuitive skills in the thirty-five persons in her classroom? Can MIT turn out 1,000 creative engineers? One of the difficulties is that the teacher himsef is likely to be intolerant of ambiguity. The teacher who allows each member of the class to develop his own interpretation of *Rip Van Winkle* is asking for confusion, and he may never get on to the next work in the syllabus.

Morison's mother was not so much an instructor as a catalyst. Now that mother's knee is fading from the scene, can the school become a catalytic agent? It is partly a matter of timing. If the curriculum meets the child at a time of wonder, the child will more likely be ensnared by the romance of Hendrik Hudson and his men bowling up a thunderstorm. Morison suggested that this is more difficult now. In the age of The Bomb the child may have lost his capacity for satisfying fantasy: All his fantasies are of horror. It was always so, Sears said, but perhaps with this difference: The bomb is part of our "rational" realm, and cannot be dealt with on the level of fantasy alone.

If the child is to blast off into the domain of the humanities, Morison suggested, literature must capture not only his sense of wonder but his sense of reality. Through literature the child organizes his own experience; only then can he realize that literature is real. Sears told us of his own shock of self-recognition after nine years of what his parents referred to as "early Christian martyrdom," upon reading Mark Twain's description of Tom Sawyer lying in the rain, muttering about how sorry they would all be when he was found dead in the morning. Pat Sears put in a caution: Does the child lose himself rather than find himself when the class reads *Tom Sawyer*—and understands him—in unison and in public? He may feel that he has tipped his myth, that the teacher has violated his secrecy. Yet, Morison argued, for every child literature offers a formula for secret sharing. Goodnow remarked that we were talking as if literature were nothing more than an exercise in group therapy; surely there is something more to say.

If literature must make contact with the child's real life, does this mean that the curriculum should begin with the familiar and move to the bizarre, as Dewey once suggested? From Batman to Shakespeare in two short years? Levin was against such "pandering," but Suppes said that what we are after is the teaching of an approach; the content is less important. And Morison added that we want to show the children that they can use in literature the intuitive skills they so ingeniously employ in their lives; this demands that the content of the literature be in some sense familiar to them. Sears said that perhaps the problem is not so difficult. Literature, by its very complexity, offers something for almost everyone. We should offer each child a smattering of content, just as we distribute enough protein through the diet so that, whatever the child eats, he will get enough.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1966—777-957